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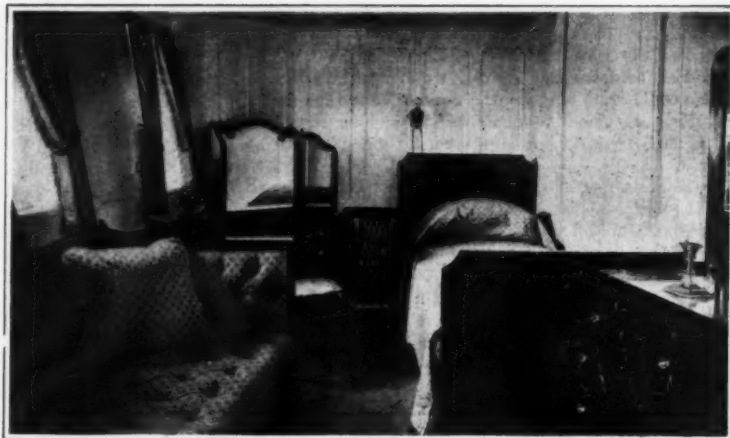
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The owner's room finished in imported Thibet oak.



Guests' room, Colonial style, enameled white walls and ceilings.



Making eighteen knots on first trial.



The music-room with dome skylight giving, by indirect lighting, the effect of daylight. Finished in Java teak. Plate glass windows are one inch thick.



Ladies' stateroom, finished in ivory white. The furniture and appointments are designed in modern style.

SEA-GOING, OIL-BURNING, STEAM YACHT "CYPRUS."—[See page 196.]

Petroleum and Its Derivatives*

The Origin and Industrial Treatment of Mineral Oil

David T. Day, Ph.D.

ORIGIN.

THE most mysterious problem in regard to petroleum is that of its origin. This is also the problem of least immediate importance to the practical development of the subject.

The reason we actually know so little about this question is because one can count on the fingers of one hand the actual experimental investigations which have been carried on to determine the origin of petroleum, while no one could state off-hand the number of learned men who have occupied volumes with ingenious theories in the hope of settling this question by the speculative method.

There are a few scientific workers who firmly believe that the source of petroleum has been absolutely settled. They go further and state the steps by which one process after another has transformed the original material into petroleum as we find it.

The rest of the scientific world is in a more fortunate condition of doubt—fortunate because in this doubt it is necessary to experiment, and to experiment is to add to our store of knowledge concerning petroleum itself.

Two reasons make the study of the origin of petroleum really worth while: First, we want to know whether the sources of supply have been sufficiently great to predict vastly greater amounts of petroleum in the earth than have yet been discovered. Second, we wish to know whether materials exist for furnishing more petroleum, or whether the ancient stores are all we may ever draw upon.

Petroleum is spoken of as "organic" and "inorganic" by the partisans of the different theories of origin.

By "organic" they seem to mean derived from material once the product of life processes, such as plants and animals. No one will doubt that petroleum as it exists is an inorganic mineral substance, because the processes by which petroleum has been formed, no matter from what sources, are evidently inorganic, and no one would confuse the oil which we call petroleum with the oils obtained by organic processes, such as the oils of animals and plants.

The theories advanced by the inorganic and by the organic groups of speculators concerning the origin of oil are plausible and interesting.

THE INORGANIC IDEA.

The general idea of inorganic origin calls attention to the earth as once a mass too hot for any element to exist in combination with another.

Accepting this idea, we know, by the experience with the electric furnace, that when the earth cooled sufficiently for elementary bodies to combine, compounds of metals with carbon—i. e., "carbides"—are among the first to form. They can exist at higher temperatures than other compounds.

As the earth cooled still further, other combinations were possible, such as hydrogen with oxygen.

We can think, then, of a primitive "carbide earth," and, as this cooled, water existing as steam in the atmosphere gradually attacked the carbides with the formation of hydrocarbons, including petroleum, which escaped into the air. After such action the earth consisted of the oxidized crust, and a carbide interior would be acted upon more and more slowly, and water penetrating through the crust would, being in smaller amount, first attack those carbides which are more easily decomposed. Occasionally masses of more refractory carbides, such as carbide of iron, carbide of aluminium, etc., would be passed by. Thus sporadic masses of such refractory carbides might remain until modern times when changes in the earth's crust had provided reservoirs covered with relatively impervious material where our present deposits of petroleum might accumulate.

According to this theory, these processes may still progress.

One of the few experimental investigations as to this theory has been carried out recently by Mr. George F. Becker, United States Geological Survey. He has shown that ammonium chloride, a common constituent of volcanic emanations, when acting upon natural masses of iron, yields its chlorine to the iron, while the hydrogen of the ammonium chloride unites with the carbon in the iron to form petroleum. He has so acted upon natural iron carbide, found in the earth, as to actually make petroleum by such means. In fact, this process can be easily illustrated to you.

Mr. Becker has also called attention to the fact that where deposits of petroleum are known there the deviations of the magnetic needle are greatest. The asso-

ciation of petroleum with magnetic material, practically iron or magnetite, seems much too close to be accidental, and it may indicate that an important part of the oil is derived from iron carbides; but Mr. Becker does not commit himself to any exclusive theory.

ORGANIC.

By far the greater number of geologists and petroleum chemists prefer the theory that petroleum has been formed from the various residues of animal and vegetable life, stored in very large quantities in the sedimentary rocks where accumulations of oil are found. These scientists have differed very greatly as to the processes which have transformed organic residues into oil. Prof. Carl Engler and his scientific associate, Prof. Hans Höfer, are convinced that they have followed out the detailed steps of the process. In brief, they believe that in the ordinary processes of animal decay, taking place under ground, the portions consisting of fats remain after the rest of the organism has entirely disappeared. These fats are hydrolyzed, and the fatty acid portion loses oxygen and becomes oil. The different oils result both from varying original materials and from the varying degrees of heat and pressure by which the material has been distilled, with oil as the end product.

Other scientists do not adhere to so detailed a conception of all stages of oil formation. Mr. David White, of the United States Geological Survey, has formulated exceptionally clearly the view quite generally held among scientific men. This theory is clear, logical and consistent. First, by the aid of bacterial fermentation—a biochemical process—the plant and animal debris is partially disorganized, with the formation of new compounds, the decomposition being interrupted at some stage short of complete destruction. Second, by geochemical and geodynamic agencies the buried debris is compressed and subjected to a process of distillation which gradually alters the organic substance and drives off volatile matter. When the organic debris consists of peat of ordinary types, or of scattered debris of vascular types of plants, the organic deposits are transformed to coal or carbonaceous matter in the shales or sandstones, etc. When the organic debris consists largely of resinous and waxy plant products, such as spore covers, seed coats, etc., deposited in comparative purity, the geodynamically and geochemically altered material (much volatile matter being evolved)—forms canneloid coals, such as cannel coal and when the original organic debris contains much algal matter, or matter supposed by most paleobotanists to be algae, mixed with other plankton material in the muds—that is, when the deposit is "sapropelic"—the partially-altered residues are oil shale, oil rock, boghead, etc. In all these cases the material, whether coal, oil rock or boghead, is already dynamochemically altered and partially distilled, some of the volatile matter (gases and oils) having already been expelled. The kinds of volatile matter depend on the geological conditions prevailing in each case, and the amount of the volatile and the extent of the reduction ("carbonization") of the residues depend primarily on the energy and duration of the dynamic action, though varying according to the kinds of original debris of plants and animals. Gases are evolved in all cases, and are still being given off in many coal fields. Oils are believed to be produced by the natural dynamochemical distillation of cannel-forming debris, though the more distinctly "sapropelic" matter is supposed to include the principal substances from which petroleum is distilled in the earth.

In some cases these layers of sapropel apparently have become indurated into layers of shaly material which is still in condition to yield oil when under pressure.

Whether our bituminous shales have thus originated or whether they owe their organic matter to infiltrations is a point which may soon be cleared up.

How long the organic matter remains as sapropel before being converted into oil is questionable, but in my judgment the greater the proportion of the total period given to the first stage and the shorter the period assigned to the petroleum after actual formation, the more probable the theory.

At this point I would like to express my lack of faith in the conservatism of the statements frequently made that oil has actually been found in process of formation from seaweed on the surface of water. Scientific accuracy seems to be entirely lacking for these obviously improbable observations.

However the organic matter may have been converted into petroleum, we recognize that the oil was at first scattered in minute drops through the earth, and these

gradually collected, largely driven by the superior capillary action of water into such porous rocks as can serve as good repositories, and where the oil is confined by comparatively impervious rocks—usually clays or shales with their capillaries filled with water. During this process of accumulation it is quite possible that the character of the oil has essentially changed. Thus oils which have penetrated into shales are found to be simpler in their make-up than those in other rocks, such as limestones. It would seem from what we find that the shales have taken out part of the original constituents, and I have proved it possible to abstract certain parts of oils merely by diffusing these complex oils through dry clay.

HOW OUR VARIOUS OILS ARE UTILIZED.

We can think of the petroleum which is produced in the West as all containing more or less of Pennsylvania oil, with greater or less admixture of asphalt, and, in the case of California oil, considerable proportions of members of the coal-tar series.

For a long time these Western oils were not taken at all seriously, inasmuch as the supply was abundant of Pennsylvania and West Virginia oils. Moreover, the Western oils—that is, of Texas and California—were very difficult to refine. A process was soon found for refining Texas oils, but the California oil remained a problem. While it was easy to remove the asphaltic material, the coal-tar oils, such as benzol, toluol, etc., distilled over with the illuminating oil and made to burn with a smoky flame. One of the chemical engineers of the Standard Oil Company of California found, however, that fuming sulphuric acid—that is, sulphuric acid containing sulphur trioxide in solution—has the property of taking out these coal-tar oils quite completely and furnishing a very satisfactory kerosene. With this discovery the refining of California oils progressed rapidly in spite of the fact that in distilling off all the available kerosene the total proportion obtained was comparatively small. This difficulty of extracting coal-tar hydrocarbons from petroleum has been met with to even greater extent in Roumanian oils, and there a still more modern process has been applied, though too recently for an estimate of its practical value. By this the distillate containing coal-tar oils is treated with liquid sulphur dioxide, which extracts the coal-tar oils in preference to the paraffin hydrocarbons, and thus renders the latter suitable for lamp oils. This ingenious process, moreover, admits of separating, finally, the coal-tar oils in a condition suitable for use, whereas they are practically destroyed when separated by means of fuming sulphuric acid. Thus to-day there are no varieties of crude petroleum in the United States which cannot be refined satisfactorily, although the yields of refined products in the West are by no means so great as with the eastern oils.

Heavy Texas and California oils can also be made to yield very satisfactory lubricating oils. A process is under way which probably will give considerable yields of paraffin wax, even from California oils, in which, naturally, almost no paraffin wax is present.

The amount of oil refined and the amount used for other purposes are now merely questions in the United States of a market for the resulting products. If all our oils were used in the United States and not exported, the oils of the East and of Oklahoma would be an abundant source for all the desired kerosene, and perhaps gasoline as well, but about one fifth of all our oil is exported in one form or another, especially kerosene.

As each year goes by, technologic improvements in the treatment of petroleum make this material more flexible for suiting all market demands, so that in general it may be said that enough oil is refined to meet the foreign and domestic demand, first, for kerosene and gasoline; then attention is given to the much smaller and more easily satisfied demand for lubricating oils; and, finally, to the ever-increasing demand for paraffin wax.

The rest of the product can always be gotten rid of at fairly lucrative prices for fuel oils. In fact, the price for fuel oil has almost doubled in the last five years.

In general, all of the eastern oils are refined to the greatest possible extent, producing gasoline, kerosene, lubricating oils, paraffin wax and a minimum of gas oil and fuel oils. In fact, it is the common practice to distill these oils entirely to coke with a production of practically no fuel oil.

As these oils are insufficient for the distillation needs of the country, large quantities of oil from Ohio, Indiana, Illinois and Oklahoma are similarly refined to the utmost limit. The same is true of the oil from the Caddo

* Paper read before the Franklin Institute and published in the Journal of the Institute.

(Louisiana) field and from the Electra region in northern Texas, where the oils are of Pennsylvania grade. Meantime the oils of Texas are largely used for fuel purposes, though a certain amount is sent in tank steamers to the Eastern States, or worked up at Port Arthur, on the Texas coast, for the production of superior lubricating oils.

Since all this does not suffice for the foreign and domestic demand for refined products, Wyoming is called on for similar use of its light-grade oils, the production of which is increasing very rapidly in the Salt Lake field near Casper.

These oils above mentioned, comprising our total supply, apart from California, amounted to about 135,000,000 barrels in 1912, while California yielded 87,000,000 barrels more. This California contribution is the really flexible quantity. It can be used in so far as necessary for refining purposes, but principally as a great source of fuel oils and for road asphalts. This supply of fuel oil will enter significantly into eastern commerce with the opening of the Panama Canal.

Since this lecture was prepared the United States Geological Survey has pointed out the existence of very large bodies of oil shales in Colorado and Utah which are richer than the Scottish oil shales. Some will yield 2 barrels of oil per ton by distillation, while the usual oil-bearing sands yield less than half that much. Shales yielding 30 gallons per ton of crude oil probably exist, according to estimates of Mr. E. G. Woodruff, of the Geological Survey, capable of yielding 15 billion barrels of crude oil.

IMPORTS.

Two other sources add to the total oil supply of the United States—namely, considerable imports of heavy Mexican crude oil, suitable principally for road asphalt and fuel oil. This Mexican importation will undoubtedly steady the price of fuel oil in the next year, as some twenty of the largest tank steamers afloat have been built for this trade and will bring large quantities to the eastern ports. The second source is light distillate, yielding large proportions of gasoline and coming from Borneo and Java to Pacific ports. Thus while we are exporting gasoline on the Atlantic Coast we import it on the western shore.

OUR RELATION TO THE REST OF THE WORLD.

The total production of petroleum in the United States is now, roughly, 240,000,000 barrels. This means two thirds, and more, of all the petroleum produced in the world. And yet the first commercial development of significance took place barely half a century ago. There is now no sea whose waters are not churned by the propellers of oil-burning steamships, no country whose roads have not seen the gasoline motor car and no village in the civilized world in which the flame of kerosene or some form of petroleum does not illuminate some house, and thousands of miles of highways are kept free from dust or otherwise improved by petroleum oil.

We owe our standing in national intelligence to the light of the kerosene lamp. We owe our greatest industrial characteristic—flexibility in manufacturing processes—to the national habit of reading. Kerosene light has been cheap, and is cheaper in the United States than anywhere else, and it has prevented all other lights from following the high price of living.

FOREIGN OWNERSHIP OF AMERICAN OIL.

Petroleum has had its share in developing American prestige. It has done more than precious metals or precious stones. Probably more people have used kerosene than have ever seen a gold coin. The petroleum and natural gas produced last year outvalued our gold, silver, lead, zinc and all other metals combined, except iron and copper.

I offer these quantities merely to stimulate the natural inquiry as to how we are administering this trust of national, natural advantage; an advantage over less favored nations which it is a pledge of our patriotism to maintain. Are we maintaining it to the best purpose? We are not. In no line of national conduct is the progress so recklessly devoid of any thought-out policy. Besides a system of production which considers neither supply nor demand at home, we squander our heritage over the face of the earth, and we do worse. It may well be claimed as good public policy that our oil should spread out to less favored lands as the handmaid of education where it will do the greatest good, and to this we must subscribe. No missionary can compete with the lamp, nor work without a lamp. But what policy broader than dollar greed can defend the sale of our greatest single weapon for national independence, our oil lands themselves, to foreign capitalists, if not to foreign nations?

The facts are open to every one, but recognized by few, that 25,000 barrels a day, over 12 per cent of the oil in Oklahoma, are produced by foreign companies, and the foreign ownership in California is increasing even faster.

The chief significance of this is that practically every foreign power is adopting oil in place of coal for its battle-ships, and a supply of oil is requisite for this purpose.

There is no opportunity here to develop a policy, but there is an opportunity for directing thought, and I bespeak the influence of this time-honored institution, developed within the sound and in the spirit of our national Liberty Bell, in giving sympathy and counsel to our National Government as to these problems when developing petroleum legislation.

SUPPLY OF GASOLINE.

This consideration naturally suggests the vital question of an adequate gasoline supply. Even if we produce 25,000,000 barrels of gasoline in the next year, this would probably be too little for a year or two of further automobile progress.

The means for meeting the demand are in sight.

This answer is far easier to state than to explain. In the first place, recent developments in knowledge of the resources of the United States make it probable that there will be no great decline in oil production in the near future, therefore no decline in gasoline supply is likely. As to the necessary increase: this will come from synthetic gasoline obtained from petroleum itself. To make this clear, it is necessary to refer in great detail to the nature of petroleum. We know that this long series of oils which mixed together constitutes petroleum begins with oils which boil more easily than ether, and each following one in the series boils at a higher temperature. By distilling out those which boil below 300 deg. Fahr. we obtain from Pennsylvania oils about 20 per cent of so-called naphtha. By redistilling this we obtain gasoline, but the naphtha itself is fairly suitable for automobiles. The mid-continent oils yield slightly smaller proportions of gasoline. The oils of northern Louisiana and Texas yield as much as Pennsylvania. The gasoline yield from the Gulf Coast of Texas and Louisiana and from California is very much less, so that at present the west coast is practically left out of consideration, and its gasoline is supplemented by importation from the Orient.

CRACKING.

After the natural yield of gasoline has been taken from crude oils, the remaining portion boils at too high temperatures to be suitable for automobiles, although the higher-boiling kerosene is used successfully under exceptional conditions which cannot be considered here. Therefore the limit of gasoline would seem to be reached—were it not for the fact that many oils break up into lighter oils when heated.

Thus, certain Mexican petroleum contains naturally only 2 per cent of gasoline, but, by slowly heating, these oils break up so that they yield about 7 or 8 per cent of gasoline. But these so-called "cracked" oils are bad smelling and difficult to refine. Several years ago I found that if these oils are distilled under pressure the yield of gasoline is still greater, and that the unpleasant odor due to deficiency in hydrogen in the composition of the oils can be remedied by actually combining hydrogen with the oil in the still under the influence of a catalytic agent. Recently the demand for any kind of gasoline has waived the requirement of good odor, and other processes are producing much synthetic gasoline. By such means low-grade residues have been made to yield from 20 to perhaps 70 per cent of their weight in material which will serve as gasoline.

THE STUDY OF INDIVIDUAL HYDROCARBONS.

The main difficulty in carrying out these processes is lack of knowledge of the behavior of individual oils when heated. At this point our fundamental study of individual hydrocarbons fails. It seems wise just at this time to encourage to the greatest extent the study of the characteristics of these individual hydrocarbons—not only to know more of the way they break up when heated, but to study the effect of chemical agents upon them in forming a long series of new substances and of old substances in cheaper or purer conditions.

NATURE OF PETROLEUM.

But what are complex and what are simple oils? What is petroleum? Petroleum is so many things under so many conditions that at first it seems hopeless to attempt to define it.

Yet we can distinguish between petroleum and all other substances as being made up of hydrocarbons and frequently holding in solution these indefinite compounds of hydrogen and carbon, with oxygen or sulphur, or both; that we call asphaltic compounds.

There are so many hydrocarbons inter dissolved in this complex mixture, usually containing different proportions of hydrogen to carbon, that they would seem to grade without solution of continuity from marsh gas through hydrocarbons containing progressively more carbon. Meanwhile, blended with these pure hydrocarbons are, frequently, the asphaltic materials, which, with ever-increasing carbon, extend the complexity of the subject through gilsonite and grahamite to the indefinite border land of coal.

We recognize that a separation of this great mixture into all its simple oils is beyond the possibility of any one man, and—to further present, frankly, the sum of discouragement which this problem presents—while we are separating these constituents, many of them are

broken up into still new oils by the very agents (heat, chemicals, etc.) which we use for their separation.

In spite of all this, the work of many scientists taken together has isolated one oil after another and simple individual oils have been taken out of the mixture. We all know that this has taught the encouraging fact that there is system in the variation of these oils one from another. We know that we can group the oils into a few homologous series, and in each series each oil differs from the next member by a definite amount of hydrogen and carbon, and with a difference in boiling-point which makes possible certain methods of separation. There is similar difference in viscosity, specific gravity, etc., which properties are also being availed of as aids in separation.

It is only recently that we have come to avail ourselves of properties which characterize each series as a whole in order to separate a whole group at once and then study its members.

GROUP SEPARATIONS.

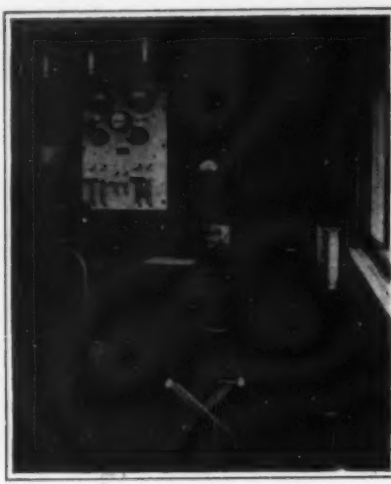
The first of these processes, historically speaking, has been to treat the complex oil with sulphuric acid, and by keeping the acid cold and using it sufficiently strong we can destroy and thus remove all of the groups except what we call paraffin hydrocarbons, and if we heat the oil we can easily attack these paraffin oils also. Lately other important processes have been added: thus Nastukoff in Russia has found that by treating oils with formaldehyde and sulphuric acid, condensation products are formed with certain groups of oils. Again, Holde and others have formulated methods for extracting certain kinds of asphalt from oils by precipitation with gasoline. These and other methods which it would lead us too far to consider have enabled Prof. Engler to formulate a general method which it is believed will soon enable us, for purposes of study, to sufficiently separate a given petroleum into its groups of components, and the study of each of these will soon give far better fundamental information of the constitution of our oils. Evidently many surprises await us as to the character of these individual oils. We are accustomed to think of the best of oils as having odors that are persistent and disagreeable. These we will find are due usually to slight amounts of impurities. Already we know odorless oils such as albolene and vaseline when fresh—that qualification "fresh" is significant and of promise. The very fact that oils develop an objectionable odor with age is significant when we learn that these odors are chiefly oxidation products allied to fatty acids, and of the greatest promise for the future production of such valuable substances as butyric, oleic, stearic and other acids. We must look upon the individual petroleum oils, therefore, as the starting point for compounds of great utility. The greatest advance which has come in the consideration of the chemical derivatives from these oils is due to recognizing that these hydrocarbons are, after all, not the refractory, inert substances that we have taken them to be, but susceptible by chemical treatment of yielding a host of products. Theoretically, this has long been possible—as a practical feature it is in its infancy. But already the oxidation products, such as fatty acids capable of being saponified into soaps, are being investigated in this city. Chlorine products are being made which offer strange new properties with suggestions of many new uses. Strangely enough, these chlorine products will not burn readily, and already some of these products of inflammable kerosene are used most effectively as fire extinguishers.

IMPROVING OILS BY ADDING HYDROGEN.

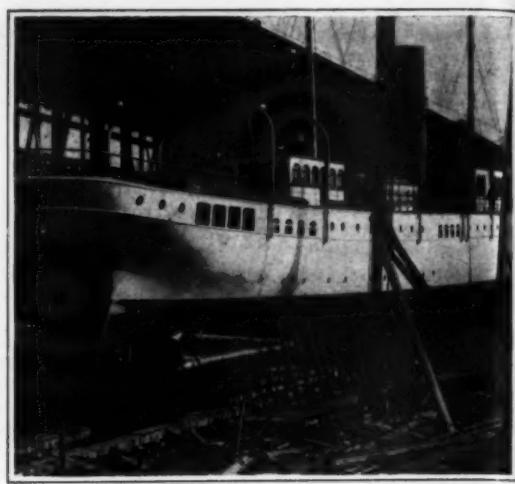
Another line of investigation is proving helpful in the direction of adding hydrogen to oils which owe their bad odor and color to lack of saturation. The chemical possibilities with these lower grade unsaturated products are problems for the future. We know at least that we can add hydrogen to them and then form the chlorine or oxygen products which have already been referred to, but beyond doubt their unsaturated condition will enable them to be acted upon directly to form other lines of valuable products. In fact, years ago, my brother, Dr. W. C. Day, then of Swarthmore College, indicated a line of valuable research by actually making good varnishes by treating waste unsaturated residues with nitric acid. We know little of what sulphur will accomplish in combination with oils. The same is true of phosphorus and other active chemical agents. The very vastness of this field of research teaches one fundamental lesson, one suggested by the coal-tar industry. It is characteristic of that industry that the individual oils were easily separable from each other, so that the fundamental properties of each could be thoroughly studied once for all, and upon that basis of thorough and exact knowledge vast stores of useful application were quickly based, yielding us, besides aniline dyes, saccharine and a host of helpful medicines. But we have no such fundamental knowledge of petroleum oils. Can there be any doubt that the quickest, surest road to the knowledge of the chemical uses for petroleum for the most successful application of it in all ways must be by promoting the study of the individual components?



Side view of library. This room has a hardwood floor, is large and comfortably arranged.



The wireless-room. It is fully equipped and of ample dimensions.



Steam yacht "Cyprus," showing steamer-type of stern with underslung rudder.

The Oil-burning Steam Yacht "Cyprus"

Ocean Liner Principles Embodied in an Ocean-going Yacht

THE "Cyprus" is a sea-going vessel designed by Messrs. Cox & Stevens for Mr. D. C. Jackling, of Salt Lake City. She is 230 feet in length and of the double-deck type, with straight stem and elliptical stern and powerful sections, being designed for the heavy weather experienced on the Pacific. She is oil-burning and carries fuel for a trip of 6,000 knots without replenishing her bunkers. The vessel is twin screw and has sufficient power to steam 19.5 knots when desired, so that she can maintain a sea speed of 13 or 14 knots very economically. She was built at the Seattle Construction and Dry Dock Company, under the superintendence of her designers, and before being delivered to her owner, underwent trials at sea, at which time she encountered a 70-mile gale and extremely heavy weather. She proved herself an admirable seaboat.

The "Cyprus" is a notable vessel in many ways. Her accommodations for owner and guests are unusual in extent, and the entire vessel is most superbly furnished and equipped. No expense was spared in the construction, not only of the hull and machinery, but of every detail, selected hardwood being imported for the various main saloons and cabins and all the furnishings and fittings being of special design.

It is worthy of note that the "Cyprus" is not only the largest steam yacht now on the Pacific coast, but is the only large steam yacht ever built on the Pacific, and in size she is outclassed by only four steam yachts owned by Americans and built in American shipyards.

The oil-burning feature of this vessel has proved most satisfactory, the designed speed having been obtained with great ease and the fuel consumption at ordinary cruising speeds being very moderate.

The "Cyprus" has many striking features. Mr. Jackling having imposed upon his architects the task of securing for him a vessel combining an unusually high maximum speed with the greatest possible accommodation for her dimensions. It was further required that the vessel should have a steaming radius of at least 6,000 knots at cruising speed, and should be suitable for extended ocean cruising in heavy weather with comfort and safety to those on board.

Having these requirements in mind, Messrs. Cox & Stevens decided upon the steamer type of hull as possessing many advantages over the conventional yacht type, in which the long overhanging bow and stern add absolutely nothing to the seaworthiness of the vessel or of its accommodation. The architects further decided that in order to enable this vessel to maintain a high speed at sea, it was better to adopt the double-deck type, and accordingly the plating has been carried right up to the upper or shade deck, a feature which permits of unusual accommodation on the main deck.

The design shows a very handsome vessel with straight stem and elliptical steamer stern, the freeboard being ample, the sheer pleasing, and the finished vessel with its large stack placed nearly amidships, two military masts arranged for wireless and its two deck-houses of steel on the upper deck, present a most workmanlike and attractive appearance.

An inspection of the lines shows a form that should be admirable both for speed and seaworthiness, there being a moderately sharp entrance and a very easy run aft, considerable deadrise to all the sections and a pronounced flare above the water line forward, which will tend to keep the vessel very dry under all conditions.

The hull is built throughout of heavy steel in excess of the underwriters' requirements. Special attention has been paid to the matter of watertight subdivision. There are nine transverse watertight bulkheads built of heavy plating; there is a complete double bottom extending the full length of the vessel, and in addition, both forward and aft of the machinery space, a heavy watertight deck has been worked, very largely adding to the safety of the ship. The space beneath these watertight decks is utilized for stowage of fuel, water, and other stores.

The form of hull decided upon has made it possible to secure an unusual amount of accommodation for the owner, his guests, and for the crew of the vessel, this having been still further increased by the adoption of two four-cylinder triple-expansion engines, using oil as fuel, steam being supplied by a battery of Babcock

& Wilcox boilers of the most approved type, these boilers being particularly suited for oil-burning.

The use of oil as fuel, while common in war vessels and in merchant ships, is practically a new development in yacht design. The adoption of twin-screw propulsion and oil fuel not only largely reduces the amount of space assigned to the machinery department, but also makes possible a considerable reduction in the engine-room force.

The fuel oil, of which the vessel has a total tankage of some 350 tons, is carried in carefully constructed tanks formed by structural watertight bulkheads and the vessel's plating, the oil being carried partly in a large thwartship tank between the boiler room and engine room, and partly forward and aft in hold tanks under the water-tight decks. All of these tanks are very thoroughly subdivided by swash bulkheads and are provided with all the most approved appliances for ventilation, filling and emptying.

The outfit of auxiliaries is most complete. The vessel is steam-heated throughout, and an elaborate system of interior telephone communication has been provided for; plumbing of the very best, supplying hot and cold running, fresh and salt water, and a large cold storage plant has been provided, making it possible to keep provisions for a long cruise in warm climates.

The hold space aft is given up to fuel tanks, water tanks, and certain storerooms, while in the forward hold there has been arranged a most complete system of storerooms, so that the vessel can store up for extended cruising.

With the exception of a small portion of the main deck taken up by the officers' quarters, the entire space on this deck is utilized by the owner and his guests. Limitation of space prevents any detailed description of these accommodations, which are well portrayed in the accompanying illustrations.

At the extreme forward end of this space is a large double-bedded stateroom extending the full width of the vessel with a bathroom adjoining, this room being equipped with two bureaus, a large sofa and two hanging wardrobes. The beds in this room, as



Fireplace in music-room.



Dining-room, looking aft.

in the case of all other staterooms on this deck, are massive mahogany beds of special design. These staterooms are all furnished in Colonial style, with massive mahogany furniture and doors, the bulkheads, ship's side and overhead being finished in ivory white. The bathrooms are all tiled on the floors and also have a wainscoting of tiling, all the fixtures being nickel-plated and the finish where not tiled being of white enamel.

A passage leads on the center line aft from this stateroom, and on each side of this passage are two extremely large staterooms, each having a full-size wooden bed, sofa, dressing table and bureau, the baths being arranged between each pair of staterooms and the wardrobes for the staterooms being set into the bathrooms, thus leaving the staterooms unusually wide and clear. Aft of these staterooms and bathrooms comes a boiler inclosure, on the port side of which is arranged a galley, officers' messroom and laundry, also a bakery and a drying-room. On the starboard side

abreast the boiler room inclosure is a passage finished in teak, and this passageway communicates with the forward quarters on the main deck, and has a lobby where companion stairs lead up to the upper deck to the dining-room.

This passage at its after end leads into the music-room, which is a large compartment 21 feet by 26 feet, and extending the full width of the vessel, finished in Java teak handsomely paneled with furniture to correspond, and having overhead a very handsome dome skylight, so arranged as to give a very beautiful lighting effect in this room.

A summary of the accommodations of the owner and guests shows that this vessel has eleven masters' rooms, six masters' bathrooms, all so arranged that their occupants may pass from one room to the other, to the music-room, library, dining-room, smoking-room and after deck space, without going out into the weather, all of the rooms being large in size and comfortably arranged. This is certainly an extraordi-

nary achievement in a sea-going vessel of the given dimensions.

Mention should also be made of the unusual speed which this vessel makes, namely, 19.5 knots with forced draft. For this speed her full boiler and engine-room capacity will be utilized and the consumption of fuel will be considerable; but at cruising speeds in the neighborhood of 14 knots she will be remarkably economical on account of her length and fine proportions, and will have a steaming radius of over 6,000 knots. With natural draft she maintains a speed of 16.75 knots. The deck and life-saving equipment of the "Cyprus" is unusually ample, as she carries on each quarter a large lifeboat, and in addition three large and powerful launches, one of these being a high-speed boat and the other two heavy, substantial launches, one being for the owner's use and the other for the service of the ship. In addition to these boats the complete equipment of life-preservers and all other appliances for safety required by law will be supplied.

Prehistoric Mines in Belgium

Flint, the "Steel" of Prehistoric Man, Systematically Mined Underground

EVERY child is familiar with the flint implements of the early races of mankind. But it is not so generally known that prehistoric man, who had to rely on such seemingly crude material as flint for his tools, was

of the stratum of chalk which is found at this depth and which contains the flint nodules valued by neolithic man. The appearance of these galleries is well shown in one of our engravings. It will be seen that the roof of the gallery is supported on natural pillars which the neolithic miners left standing as they dug their way through the chalk. All the work of sinking the shafts and cutting the galleries was done with primitive picks about eight inches long, of which over 1,500 specimens have been found, two of them appearing in one of our engravings. On the walls and roofs are found the marks of these primitive picks. A specimen thus torn from the wall of a gallery is seen in one of our engravings and shows very clearly the marks of the picks. The excavation of these mines by such primitive tools represents a vast amount of labor. For over an area of 500 square yards there were found nine shafts, varying from 8 to 25 feet apart. The total number of shafts made by these neolithic miners is estimated at hundreds or even thousands. On the sides of one of the shafts exposed by the explorer, it was observed that a number of holes were cut in pairs facing each other. Evidently pieces of timber had been laid across the shaft at these points, so as to form a kind of ladder for entering and leaving the mine. It is interesting to note that these beams were arranged in a rough spiral staircase, displaying considerable ingenuity on the part of prehistoric man.

While flint is found at varying depths in these mines, the material which is of sufficiently high grade to serve for tools occurs only in the lower strata, so that a great deal of excavation was thus rendered necessary. The valuable stratum has a thickness of only 20 inches, and in some places even less, and the miner was thus obliged to cut his way in a crouching position. Fragments of pottery were found here and there, but only in rare cases. There can be no doubt that the miners must have used some kind of primitive lamps, but no evidence of these could be discovered. It is estimated that the mines were worked at about the year 2,000 B.C. and at the mouth of the shaft evidence remains of the work of clipping the flint, leaving no doubt as

to primitive methods employed by the miners in shaping their tools.

These remarkable mines form only one of the numerous examples, with which the ethnologist is constantly



Fragment from wall of one of the galleries, showing the marks left by the flint picks of the miners.



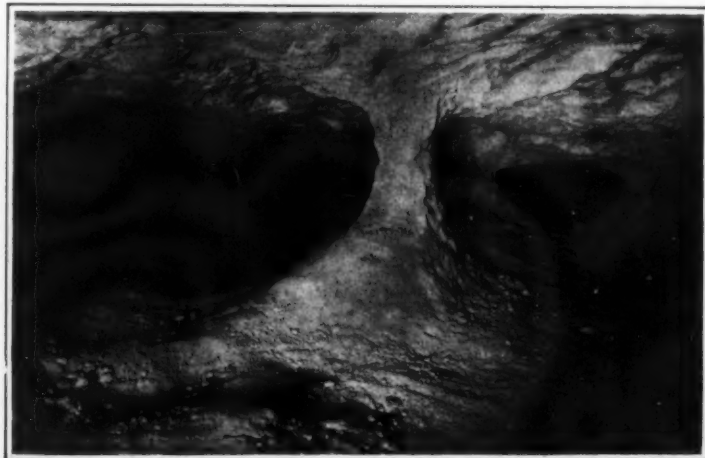
Numerous flint picks such as those shown in this photograph were found in the prehistoric mine.

so far advanced in his technical civilization as to carry on systematic underground mining operations in search of his "metal." That this was indeed the case is abundantly shown by the mines discovered near Mons, in Belgium, of which we show several illustrations.

These mines comprise numerous shafts which go down to varying depths up to 50 feet. Connecting the bottom of these shafts are many galleries cut out

meeting, of the comparatively advanced industrial and esthetic civilization of the primitive races of men, whom we are altogether too apt to think of as almost devoid of the kind of intelligence which we think characteristic of our era.

For the facts here presented and for the photographs reproduced we are indebted to M. E. Rahr, of the Royal Museum of Belgium, who takes an active part in the excavation.



Natural pillars were left by the miners in cutting galleries through the flint-bearing chalk.

Our Present Physical Knowledge of X-Rays*

A Synopsis of Their Most Important Properties

By Wheeler P. Davey, X-Ray Laboratory, Department of Physics, Cornell University

GENERAL PROPERTIES OF X-RAYS.

THERE are certain general properties which are common to all X-rays. Among these are:

- (1) The fluorescent effect.
- (2) The photographic effect.
- (3) The ionizing effect.
- (4) The chemical effect.
- (5) The action upon a selenium cell.
- (6) The penetrating effect.
- (7) The physiological effect.

(1) Certain uranium compounds and certain salts of alkali and alkali-earth metals have the property of giving off light when exposed to the action of X-rays. When the intensity of the radiation is increased (as, for instance, by bringing the source nearer) the intensity of the fluorescent light is increased. Röntgen¹ does not find any general simple relation between the P. D. applied to the tube (as measured by the current in the primary of his induction coil) and the amount of fluorescence produced on a screen of barium platino-cyanide, but states that in some cases he has been able to get the two in direct proportion to each other. But with constant conditions of excitation for a given X-ray tube, the intensity of the fluorescent light from the screen always varies inversely as the square of the distance from the screen to the target of the tube.

(2) The action of X-rays upon a photographic plate at a given distance from the tube depends partly upon the current sent through the tube and partly upon the penetrating ability of the rays employed. Other things being equal, an increase in the current hastens the photographic action, while an increase in the penetrating ability of the rays makes it slower. Two X-ray beams which produce equal effects upon a fluorescent screen do not necessarily produce equal effects upon a photographic plate.²

Luther and Uschloff³ thought they detected a difference between the action of X-rays upon a silver gelatino-bromide plate and that of light upon the same plate. It is possible that their results may be explained upon the same basis as solarization.

(3) If a gas is exposed to an X-ray beam, it is broken up into ions, or electrically-charged atoms. While the quantity of charge carried by different ions is not always the same, still it is always some exact whole number times 4.9016×10^{-10} electrostatic units of charge.⁴ The sum of all charges carried by all the ions of a given sign is often used as a measure of the quantity of radiation which has produced them. As the sum of all the + charges must necessarily exactly equal the sum of all the - charges it is immaterial which sign of charge is used in the measurement. The amount of ionization produced in a gas in a given time depends upon the inverse square of the distance from the target of the tube,⁵ the P. D. applied to the tube,⁶ the penetrating ability of the rays,⁷ the nature of the gas,⁸ the pressure of the gas,⁹ but is independent of the temperature of the gas.¹⁰

(4) Except for the action of X-rays upon the materials in the film of a photographic plate, the only chemical actions so far noticed seem to be a precipitating effect, a dehydrating effect, a hydrolytic effect. Iodine is precipitated from its solution in chloroform by exposure to the rays.¹¹

Schwartz has found an ammonium oxalate-mercury bichloride mixture which precipitates calomel under the action of X-rays.¹²

Ammonium, potassium, barium and magnesium platino-cyanides change color when exposed to X-rays, due to dehydration.¹³

When starch is exposed to the rays it is changed into soluble starch and then into dextrin.¹⁴

(5) X-rays affect the electric resistance of a selenium cell in the same manner as light.¹⁵

(6) All substances exert more or less of an absorbing effect on X-rays. In general, the absorbing effect of any given substance for a given bundle of rays depends upon the material used as a target in the tube, the nature and thickness of the absorbing substance, the history of the radiation after leaving the target and the P. D. across the tube at the instant the given bundle of rays is given off. In general, if the target of the tube is a substance of high atomic weight, then rays from that tube will be less readily absorbed than if the target had been of low atomic weight.

When rays from an ordinary X-ray tube pass through a substance, some of the radiation is absorbed, so that emergent beam acts more feebly on a fluorescent screen, photographic plate, selenium cell or ionizing chamber. If rays from a platinum-target tube, operating under ordinary working conditions, are made to pass through silver, then the intensity of the emergent beam may be calculated from the formula.

$$I_2 = I_1 e^{-\lambda x}$$

in which I_1 = intensity of the incident beam.

I_2 = intensity of the emergent beam.

e = base of natural logarithms = 2.7182 +.

x = thickness of the absorber.

λ = coefficient of absorption of the substance used as absorber. λ is very approximately independent of the thickness of the silver.¹⁶

All substances for which the above law holds true are said to be "radiochromic." If, however, the rays are made to pass through sheets of aluminium, tin, etc., the above law does not hold. The value of λ as calculated by the formula is different for different thicknesses of the absorbing sheet, but as the thickness is increased, λ approaches more and more nearly to a constant value,¹⁷ and the law holds approximately if the sheet is thick enough. The formula may also be made to apply approximately if the difference in thickness between two absorbing sheets is so small that the value of λ has not changed appreciably, due to the change in thickness. Absorbers which act in this way are said to be "radiochromic," and are often called "filters."

These facts may be explained by assuming that an X-ray tube sends out a complex radiation ("heterogeneous beam") having two, and sometimes three, components. For the justification of this assumption see page 199. In radiochromic substances the coefficients of absorption for the component beams are approximately the same. In radiochromic substances the beams are unequally absorbed. If the filter is thick enough to completely absorb all but one of the components, the emergent beam is said to be "homogeneous," and the absorption law will hold accurately for any absorber through which the beam may subsequently pass, provided no secondary rays are produced. It is to be noticed that no substance is absolutely radiochromic. Silver is probably the most nearly radiochromic metal for the rays given off by a tube with a platinum or platinum-iridium target, but is quite radiochromic for the rays given off by a lead target,¹⁸ being more opaque to the "secondary" component than to the "primary" component of the beam. If the absorber is of the same material as the target, it is more opaque to the "primary" component than to the "secondary" component. But the two absorption coefficients may be so nearly equal as to cause the absorber to appear under some conditions to be almost completely radiochromic.¹⁹

If the absorber is of the same material as the target, then λ decreases as the P. D. across the tube is raised, and the decrease of λ with the increase of P. D. is much more marked the higher the P. D. employed.²⁰

If the absorber is a chemical compound, the total absorption under any specified conditions is the sum of the various absorptions caused under those conditions

by the various atoms and radicals of which the absorber is composed.²¹

(7) When X-rays are directed toward a given layer of flesh, in general, some of them pass through, while others are absorbed and give up their energy to the flesh. If sufficient energy is thus delivered to the flesh, serious pathological changes result which are of great importance from the viewpoint of the physician, but which do not concern the physical investigator, aside from the question of his own self-protection. A person in good health may have several radiographs taken (sufficient for ordinary diagnostic work) by a well-informed operator, without any danger of an X-ray burn, but the operator, or research physicist, must, because of the possibility of long-continued exposure, or more often because of frequent repetition of short exposures, protect himself most carefully. The German Röntgen Society²² recommends that the protection consist of at least 2 millimeters of sheet lead, 8 millimeters of X-ray proof rubber impregnated with lead, or lead glass from 10 to 20 millimeters thick.

(8) Besides exhibiting the above-mentioned characteristic properties, X-rays also show properties which have caused them to be classed as a form of wave motion. When a narrow beam of X-rays is passed through a crystal parallel to a cleavage plane the emergent beam is broken up into a number of smaller beams symmetrically placed so that the effect as shown on a photographic plate gives the appearance of a diffraction pattern.²³

Stark²⁴ contends that this is not a true diffraction pattern, but most writers assume that the evidence points toward a true diffraction, and the theoretical basis of such an assumption is given by M. Laue, W. L. Bragg and G. Wulff.²⁵

The results of Friedrich and Knipping's experiments point to a wave length for X-rays of the order of 10^{-8} centimeters. This is of the same order as the value given by Planck's theory and as the value found by Walter and Pohl.²⁶

When a pencil of X-rays is allowed to impinge on the cleavage face of a crystal at grazing incidence, a portion of the beam is reflected and the angle of reflection is equal to the angle of incidence.²⁷ Since this reflection is from the molecules of the cleavage face, the effect corresponds to that obtained when light is allowed to fall on a reflection diffraction grating, and there appears not only the truly reflected beam, but also a series of interference bands.²⁸

Experiments with magnetic fields show that no measurable deflection is produced even by a magnetic field of 19,000 gauss. No experiments on the velocities of X-rays have been conclusive.

PRIMARY X-RAYS.

If negatively-charged particles of matter (variously called corpuscles, β particles, cathode rays and electrons) are shot out at high velocities toward a target, they will experience a great decrease in velocity upon entering the face of the target, and during the time that this decrease in velocity occurs, X-rays are produced. Such rays are called "primary rays." Although the point has not been as yet definitely settled, their properties seem to depend only upon the rate of retardation which the charged particles experience at the target, and this, in turn, depends very approximately upon the square root of the P. D. across the tube, upon the pressure of the gas in the tube and upon the atomic weight of the target.

When the cathode rays strike the target, they are not stopped instantaneously at the surface, but merely suffer retardation, so that they penetrate for some distance

* W. Seltz, *Phys. Zeitschr.*, 13, pp. 476-480, June 1st, 1912. Blennard and Labesse, *Comptes Rendus*, 1896, cxvii, pp. 723-725.

²² Archives of the Röntgen Ray, July, 1913.

²³ W. Friedrich, P. Knipping, M. Laue, K. Bayer, *Akad. Munchen. Ber.*, pp. 302-322, 1912. *Le Radium*, 10, pp. 47-57, Feb., 1913. M. de Broglie, *Comptes Rendus*, 156, pp. 1011-1012, March 31st, 1913. T. Terada, *Nature*, 91, pp. 125-126, April 10th, 1913; p. 213, May 1st, 1913.

²⁴ *Phys. Zeitschr.*, 13, pp. 973-977, Oct. 15th, 1912.

²⁵ W. Friedrich, P. Knipping, M. Laue, loc. cit. W. L. Bragg, *Camb. Phil. Soc. Proc.*, 17, 1, pp. 43-57, Feb. 14th, 1913. G. Wulff, *Phys. Zeitschr.*, 14, pp. 217-220, March 15th, 1913.

²⁶ Walter and Pohl, *Ann. d. Phys.*, 20, 2, pp. 331-354, May 21st, 1909.

²⁷ W. L. Bragg, *Nature*, 90, p. 410, Dec. 12th, 1912. C. G. Barkla and G. H. Martyn, *Nature*, 90, p. 435, Dec. 10th, 1912.

²⁸ C. G. Barkla and G. H. Martyn, *Nature*, 90, p. 647, Feb. 13th, 1913. *Phys. Soc. Proc.*, 25, pp. 200-214, April 15th, 1913. E. Hupka and W. Steinhaus, *Deutsch. Phys. Gesell. Ver.*, 15, 5, pp. 162-163, March 15th, 1913. H. B. Keesom, *Nature*, 91, p. 111, April 3rd, 1913. E. A. Owen and G. G. Blake, *Nature*, 91, p. 135, April 10th, 1913. H. S. Allen, *Nature*, 91, p. 268, May 15th, 1913. E. Hupka, *Nature*, 91, p. 267, May 15th, 1913.

* Reproduced from the *Journal of the Franklin Institute*.

¹ W. C. Röntgen, *Wied. Ann. d. Phys. u. Chem.*, 64, 1898.

² W. C. Röntgen, loc. cit. J. O. Heinze, Jr., *Amer. Jour. Sci.*, 13, pp. 313-314, April, 1902.

³ R. Luther and W. A. Uschloff, *Phys. Zeitschr.*, 4, pp. 866-868, Dec. 15th, 1903.

⁴ R. A. Millikan, *Science*, 32, pp. 436-448, Sept. 30th, 1910.

⁵ E. W. B. Gill, *Phil. Mag.*, 23, pp. 114-121, Jan., 1912.

⁶ W. Hillers, *Wied. Ann.*, 68, 2, pp. 196-232, 1899.

⁷ R. K. McClung, *Phil. Mag.*, 7, pp. 81-95, Feb., 1904. *Nature*, 69, pp. 462-463, March 17th, 1904. *Phil. Mag.*, 8, pp. 357-373, Sept., 1904.

⁸ O. G. Barkla, *Nature*, 80, p. 187, April 15th, 1909.

⁹ J. A. Crowther, *Camb. Phil. Soc. Proc.*, 15, pp. 34-37, Feb. 23rd, 1909. *Roy. Soc. Proc., Ser. A*, 82, pp. 103-127, March 10th, 1909.

¹⁰ J. H. Clo, *Astrophys. Jour.*, 33, pp. 115-124, March, 1911.

¹¹ H. Bordier and J. Gallimard, *Arch. d'Elect. Med.*, 14, Aug. 10th, Sept. 10th, 1906.

¹² G. Schwartz, *Wein. Med. Presse*, 1906, xlvii, 2092. *Electrotech. u. Maschinenbau*, 25, p. 452, June 9th, 1907.

¹³ Bordier and Gallimard, *Arch. d'Elect. Med.*, May 10th, 1905. G. Holtschnecht, *Arch. d'Elect. Med.*, Oct. 10th, 1910.

¹⁴ Colwell and Russ, *Arch. of Middlesex Hosp.*, xxvii, p. 63.

¹⁵ Perceau, *Comptes Rendus*, 129, pp. 956-957, Dec. 4th, 1899. Athanasiadis, *Ann. d. Phys.*, 27, 4, pp. 890-896, Nov. 26th, 1908.

¹⁶ J. Beloit, *Arch. d'Elect. Med.*, Aug. 10th, 1910.

¹⁷ W. Seltz, *Ann. d. Phys.*, 27, 2, pp. 301-310, Oct. 15th, 1908. J. Beloit, loc. cit.

¹⁸ W. R. Ham, *Phys. Rev.*, xxx, 1, Jan., 1910, pp. 104-105, 118-120.

¹⁹ G. W. C. Kaye, *Camb. Phil. Soc. Proc.*, 14, pp. 236-245, Oct. 15th, 1907. *Roy. Soc. Proc. Phil. Trans. A*, 209, pp. 493-451, Nov. 19th, 1908. W. R. Ham, *Phys. Rev.*, xxx, 1, p. 112, Jan., 1910.

²⁰ W. R. Ham, *Phys. Rev.*, xxx, 1, pp. 108, 111-113, Jan., 1910.

into the body of the target. After once entering the target, the particles no longer all move in the same general direction, but travel more or less radially. If, for a given velocity of cathode rays, we imagine the target to be made thicker and thicker, a thickness will be reached at last for which there are as many particles emerging in one direction as in any other. This thickness is called "the depth of complete scattering."²² In aluminium it is 0.015 centimeter; in copper, 0.001 + centimeter; in silver, 0.001 + centimeter; in gold, 0.00020 centimeter; in lead, 0.00025 centimeter at 90,000 volts. It varies directly as the voltage employed across the tube.

Those primary rays which are able to overcome the absorbing effect of the target reach the surface and emerge into the vacuum space of the tube. Measurements have shown²³ that if the P. D. across the tube is made very small, then the primary rays, at the moment of generation, have their maximum of intensity in a direction perpendicular to the cathode stream, and a minimum of intensity in a direction parallel to the cathode stream. This effect is called "polarization." As the P. D. across the tube is increased, the polarization is decreased, until finally it becomes immeasurable. This is explained by assuming that at the higher potentials the rays formed by the initial retardation of the cathode stream are negligible in their effects when compared with those rays which come out in all directions from the depth of complete scattering.

SECONDARY RAYS.

When X-rays of sufficient penetrating ability are made to impinge upon a substance, that substance itself becomes a source of X-rays, which are called "secondary rays," and in general these secondary rays have penetrating abilities widely different from the exciting or "primary" rays, and the penetrating ability depends upon the substance used as a radiator.²⁴

Radiators may be divided in the order of their atomic weights into four groups, as shown below. The radiations given out by the members of each group are very much alike.

Group 1 (1-32).—H-S. When excited by a beam from a "soft" tube the members of this group give off little, if any, real secondary radiation, but rather a scattered (one might almost say "diffusely reflected") radiation which is of the same nature as the exciting beam, and which is polarized in a plane perpendicular to the direction of the parent cathode stream. If the tube is made moderately "hard" (i. e., if it gives off moderately penetrating rays), then a slight amount of true secondary radiation shows itself, and if the tube is very "hard," a well-defined secondary beam is given off having a penetrating ability much different from that of the exciting rays.

Group 2 (52-65).—Cr-Zn. This group gives off a beam composed almost entirely of a true homogeneous secondary radiation even when excited by rays from a "soft" tube, but this radiation has little penetrating ability. With a given excitation, the ionization produced by it is almost 100 times that produced by an equal mass belonging to group 1.

Group 3 (107-125).—Ag-I. If the exciting beam is only of moderate penetrating ability, this group gives off mostly a scattered radiation, but, unlike that from Group 1, it is unpolarized, and there is a noticeable amount of true secondary radiation present. The relative amounts of scattered and secondary radiation vary greatly with small changes in the character of the exciting rays.

Group 4 (183-206).—W-Bi. These substances resemble Group 2 in their action. For all the above elements the penetrating ability of the true secondary rays is independent of the intensity or of the penetrating ability of the exciting beam, but is a periodic function of the atomic weights of the radiating elements.²⁵

If the radiator is a chemical compound, the component atoms and radicals determine the character of the secondary rays produced.²⁶

The rays coming from salts are composed of (1) a homogeneous radiation having the same penetrating ability as that from the metal itself, and (2) a scattered primary radiation considerably more penetrating than (1) due to the acid radical. If a metal occurs in the acid radical it has no individual effect, but merely acts along with the rest of the radical.²⁷

Barkla and Sadler²⁸ have shown that if the incident primary rays are less penetrating than are the secondary rays which are characteristic of the radiator used, then no secondary rays are produced, but if the incident primary rays are more penetrating than the characteristic secondary radiation, then secondary rays are produced.

The production of secondary X-rays is very analogous to the production of fluorescent light. In fact, the analogy is so close that some writers are adopting the term "Fluorescence Röntgen radiation." If the penetrating ability of the exciting primary rays is increased beyond that necessary to first excite secondary radiation, it is often possible to obtain from the same radiator still another group of secondary rays having a different penetrating ability than the first, but this second group seems always to be identical with the first group from some other radiating substance.²⁹

Chapman and Piper³⁰ tried to detect a continuance of secondary radiation after excitation from the primary rays had ceased, but were unable to detect even 1/250 of the original radiation 1/3000 second after the exciting primary rays were removed.

It has been noted above that the primary rays from the target of an X-ray tube must pass through a thickness of the target before they can emerge. It would be expected that such rays would excite that secondary radiation which is characteristic of the substance used as a target. There is also some evidence to show that the cathode stream itself may cause the target to give off its characteristic radiation if the velocity of the cathode stream is large enough.³¹

Ham³² has been able, by the use of proper absorbers, to filter out the secondary rays coming from his tube, leaving only the primary rays. He found that the ratio of the secondary radiation to the primary was increased by an increase in the P. D. across the tube. The rays coming from an ordinary X-ray tube are, therefore, heterogeneous, and since the P. D. necessary to cause a discharge to pass through the tube varies with the condition of the tube this heterogeneity is constantly changing.

On account of the wide variation in the character of the rays from tubes with the P. D. and current employed from instant to instant, it is essential that practically all experimental data concerning the action of X-ray tubes or of the rays themselves be accompanied by a statement showing:

(1) The P. D. employed and its wave form. If the maximum P. D. is measured by a spark-gap, the exact shape and dimensions of the terminals of the gap should be given. If the P. D. is measured by some other means, complete description should be given. If the wave form is not known, complete description should be given of the means used to obtain the exciting current.

(2) The number of milliamperes used and the kind of milliammeter used (that is, E. M., hot wire, etc.). If the tube is of the Lillienfeld type,³³ the size of the regulating current must also be given.

(3) Exact description of the tube, including maker's name, serial number (if any), classification given by maker, dimensions, material used as target, hardness of tube at time of experiment, and condition of tube (i. e., "grows harder with use," "hardness nearly constant," or "grows softer with use").

(4) Number of seconds the tube is used for one "run." Much of the published data to date is useless because of the failure to record one or more of the items mentioned above, since without such information the results can neither be interpreted properly nor exactly duplicated by any other experimenter.

MEASUREMENT OF QUALITY, QUANTITY AND INTENSITY.

The penetrating ability of an X-ray beam is called its "quality." It is usually arbitrarily measured by the thickness of aluminium which will permit the same intensity of radiation to pass through it as passes through a standard thickness of silver. Equality of intensity is determined either by means of the illumination of a fluorescent screen or by the blackening of a photographic plate. There is no experimental evidence that measurements of the same beam made in the two ways will agree, but it may be possible that some fluorescent screen may be found which will have the same effect as some particular photographic plate.

There are several methods in use for measuring the quantity of radiation passing a given point in a given time. Among these are:

(1) Precipitation of iodine from its solution in chloroform.

(2) Precipitation of calomel from a mixture of ammonium oxalate and bichloride of mercury.

²⁸ Barkla and Sadler, *Nature*, 80, p. 37, March 11th, 1909.

²⁹ R. Whiddington, *Nature*, 88, p. 143, Nov. 30th, 1911. J. C. Chapman, *Roy. Soc. Proc.*, Ser. A, 86, pp. 439-451, May 8th, 1912.

³⁰ Chapman and Piper, *Phil. Mag.*, 19, pp. 897-903, June, 1910.

³¹ R. T. Beatty, *Roy. Soc. Proc.*, Ser. A, 87, pp. 511-518, Dec. 13th, 1912.

³² W. R. Ham, *loc. cit.*

³³ Fortsch. a. d. Gebiete d. Röntgenstrahlen, vol. 20, No. 5, 1913, p. 448.

- (3) Change in color of barium platino-cyanide.
- (4) Total ionization produced in air by the rays.
- (5) Density of blackening of a photographic plate.
- (6) Heating of a bolometer.
- (7) Change in resistance of a selenium cell.

(8) The quantity of radiation is taken as proportional to the product of the P. D. across the tube, the current through the tube, and the time.

The first method has the objection that X-rays are not the only means of causing the precipitation. In method 2 a fresh solution must be employed for each reading. In spite of the fact that method 3 is open to the same objection as method 1, it has met with some favor, and there are numerous types of dosage-meters based on this principle, each with its own scale of tints. Tables have been published (for instance, in *Arch. d'Elect. Med. du Bordeaux*, July, 1910) by which readings taken on any of the arbitrary scales of the above three methods may be converted into the reading on any of the other arbitrary scales, but the scales in method 3 are only accurate for rays within some definite range of hardness. These three methods have the great advantage that they record instantaneously the quantity of radiation absorbed by the instrument, and may, therefore, be used as dosage-meters. Method 4, although it may be made very exact and although it is excellent from the point of view of the physicist, is unsuited to the requirements of the physician, in that it cannot be well used in the summer. It has not been checked against the other methods. If the hardness of the tube and the kind of plates and method of their development are specified, method 5 is useful in cases where it is not necessary to shut off the tube as soon as a certain quantity of radiation has been given off. Methods 6 and 7 have not as yet found much favor. They have not been checked against the other methods. Method 8 is entirely empirical for each apparatus, and a change in any part of the outfit necessitates a new calibration. Although a given operator may use this method with his particular outfit, he cannot easily compare his data with that of another operator having an outfit which differs from his own in any respect.

Intensity has been measured in three ways:

(1) Variation of distance from the tube (all other conditions being unchanged).

(2) Brightness of a fluorescent screen.

(3) Quantity per second (measured by any method given in the previous paragraph).

Method 2 cannot be used to compare heterogeneous beams of different compositions, and as a result is not accurate when used to compare the rays given off by a tube at one time with the rays given off by the same tube at another time under even slightly different conditions. Method 3 is open to the advantages or disadvantages of the particular method employed to measure quantity.

Electric Iron Production on a Large Scale

The well-known Stora Kopparbergs Bergslags Company, in Dalecarlia, Sweden, has prepared plans, ready for being realized, intended greatly to increase the company's production of iron and steel. The plans comprise an increase from 100,000 tons to 300,000 tons annually, of which 200,000 tons are to be manufactured electrically. This imposing increase in the output (which means an increase of 25 per cent in the annual production of iron for all Sweden) will require 60,000 to 70,000 electric horse-power, obtained from an increased exploitation of the company's own waterfalls, besides an increased annual output of some 500,000 tons of ore from the company's own mines. The company, however, fully intends to adhere to its old principle not to export raw material, but only finished rolling-mill products, and to supply the home manufacturers with cheap raw materials, and the building trade and railways with girders, rails and shape-iron. The extensions naturally are only intended to be brought about gradually, but according to the present plans the scheme will be fully completed in the course of ten years. Experiments are being carried on at present with Helffenstein's electric furnace, which certainly has not been so fully practically tested and worked as the Swedish furnace of the Elektrometal Company, but the former has the great advantage for works on a large scale that it can stand a very large current. The latter furnace, it is generally understood, cannot adequately employ a higher input of electric energy than 3,000 horse-power, or a not very important excess of that figure, whereas the Helffenstein furnace seems able to work with as much as 10,000 to 12,000 horse-power. The latter, it is expected, will therefore yield a more advantageous result when the production is on a large scale. Other branches of this comprehensive and typically Swedish concern are also being extended, with good results.—*Engineering*.

CANADA has established a forest products laboratory in connection with McGill University at Montreal, on the lines of the United States institution of the same sort at the University of Wisconsin.

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²⁷ J. A. Crowther, *Phil. Mag.*, 14, pp. 653-675, Nov., 1907.

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Huron River drive, Flat Rock village, Wayne County, Mich.

View looking east along the concrete road.



The Grand River road, Wayne County, Mich.

The children have discovered advantages in this concrete road.

The Use of Concrete in the Construction of Roads

A Recent Development With Much Promise for the Future

By Charles E. Foote

THE adoption by the State of New York of a standard specification for the construction of concrete roads on the State highway system, emphasizes the growing use of Portland cement concrete in the building of country highways throughout the various states.

Less than five years ago concrete roads were practically unknown. Isolated sections had been built for experimental purposes, and in a single instance, so far as is currently known, a concrete road had been in existence for a period of fifteen years. That was at Bellefontaine, Ohio. It was built in 1893, was 4,400 square yards in area, and had cost one quarter of one cent per square yard per year for maintenance. It was still in good condition in 1909, and is in good condition in 1914, though the maintenance or repair charges have increased to one half cent per square yard per year.

According to most road builders, both professional and lay, there were insuperable objections to concrete roads. They were too hard; they would lame the horses. They were too slippery in wet weather; horses would fall, and automobiles would skid on them. They were too glaring; the eyesight of animals and drivers would be injured. They were too rigid; they would crack and become ruined by temperature changes. These and divers other reasons were urged by engineers and contractors as objections to the use of concrete, rather than as difficulties to be overcome.

Still, a number of experiments were made of short sections. On the Cornell University grounds of Ithaca, New York, a 100-foot section of an experimental road was built of concrete. In the Borough of the Bronx in New York city a similar section was constructed. Later experiments were made near Washington, D. C.; near Harrisburg, Pa.; near Davenport, Iowa, and near Joliet, Ill.

But the only real building of concrete roads that was begun in 1900 was in Wayne County, Michigan, the county in which Detroit is located. Detroit is a great automobile manufacturing center, and the quality and quantity of the mud, when the roads were bad, was not conducive to the welfare of the industry. It was, of course, patent to every one that Portland cement concrete would make roads that would be hard and presumably durable; they would at least keep the travel out of the mud. To overcome the other objections experiments must be made.

The Wayne County Highway Commission went to work to build concrete roads. In the first place, contracts were let, but that method was shortly discarded; a force was organized, machinery purchased, material contracted for, and the road building conducted on force account.

From time to time the specifications were changed, mostly in the direction of strengthening the mixture. Various methods were devised to prevent the formation of cracks owing to variations of temperature. Different devices were employed to protect the concrete at expansion joints. All these and other experiments were tried with the purpose of developing the best practice.

At the beginning of 1912 the specifications which are

now in use were adopted. These specifications call for a mixture composed of one part of the very best Portland cement, one and one half parts clean sharp sand, and three parts broken stone or gravel, ranging up to one and one half inches in size. The concrete is mixed in mechanical "batch" mixers, and the quantities and quantities are very carefully inspected, to secure entire uniformity of product. Soft steel plates are used to protect the corners of the concrete at the transverse expansion joints, which are placed every twenty-five feet, and no twenty-five foot section must be left uncompleted at the end of a day's work.

Every possible means is employed to accomplish the work economically and well. Broken stone is purchased and hauled to the proper locality during the winter previous to its use, when such action will save money. Traction engines hauling dump wagons are used whenever money can be saved that way, and the cost analysis easily demonstrates on what hauls they are most economical. Water is piped or pumped, or both, and sometimes long distances, when the circumstances require; and a plant has been installed for the manufacture of concrete drain and culvert pipes, under roof, when the weather is such that work cannot go on in the open.

The men live in camps, and are housed in tents. Each contributes a certain amount from his wages to maintain the cuisine. Among the different camps a spirit of emulation is engendered as to which shall accomplish the most and the best work.

In the summer of 1912, and again in 1913, many highway engineers and delegations visited the roads of Wayne County, seeking knowledge. Most of the State highway engineers and many officials were among those who made the pilgrimage. In addition there were road experts from Great Britain, Holland, France, and Canada, and perhaps other foreign countries. All wanted to investigate to the fullest extent the principles, methods, and practice employed in the construction of concrete highways that would stand, and that would be serviceable and free from most of the objections.

Different reports were made by the visitors. All found cracks in the concrete roads, more or less numerous according to the methods by which the roads had been put down, the earliest roads showing the most cracks. These cracks, however, seem practically all to have been made during the first season, indicating a less tendency in that direction under the later specifications. These cracks are invariably filled with a bituminous material as soon as they are wide enough to receive it, and no less an authority than George W. Cooley, State Highway Engineer of Minnesota, says that they do not materially injure the road.

The result of this inspection by highway experts has been to give a tremendous impetus to concrete roads throughout the United States. It is safe to state that more concrete roads were built or projected during 1913 than in the entire previous period since Bellefontaine put down its little stretch in 1893.

Probably the most extensive concrete road work yet designed is the State highway system of California.

Over thirteen hundred miles, constituting approximately half of the State system of highways, has been planned to be constructed of concrete, and at the latest report (August 1st, 1913) something over two hundred miles were either completed or approaching completion, with nearly as much more under contract.

The specifications for the concrete mixture in the California roads follow closely the more recent practice in Wayne County; but the road is not nearly so thick, the great majority of the mileage only amounting to four inches, while Wayne County, on main roads, insists on seven inches in the center and six on the sides. The Wayne County main roads are sixteen feet wide, while those of the Sunset State are fifteen feet. It may be stated, however, that the California roads are made wider, and the depth of concrete increased to six or seven inches, as cities and populous centers are approached.

Another difference between the Badger and the Sunset roads is that while the former are given a roughened surface by "brooming," which destroys the glare of the white surface, and also eliminates the slipperiness, the latter are treated with an application of a special quality of asphaltic oil and sand, about three eighths of an inch thick. According to Mr. A. B. Fletcher, State Highway Engineer of California, this bituminous surfacing is not expected to last more than three or four years, when it can be replaced at a trifling cost which will be applied to the maintenance charge. This bituminous surfacing is not materially different from that applied to the Massachusetts macadam roads, which has proven very satisfactory.

The use of concrete on the California highways was adopted after a most exhaustive study of all the conditions. The Highway Department was confronted with the necessity, under the law, of improving a given mileage within a certain limit of expenditure. These concrete roads were considered the only practicable and satisfactory roads possible under the circumstances. The average limit of cost is figured at \$8,620 per mile.

In the summer of 1912 the commissioners of Winona County, Minnesota, decided to abandon macadam construction on the county highways, and steps were taken to investigate the use of concrete. In accordance with this decision, a committee consisting of three of the commissioners, an influential citizen and a deputy engineer accompanied Mr. George W. Cooley, State Highway Engineer, on a tour for the inspection of concrete highways in different localities.

The chief interest in the trip was centered in the Wayne County highways, as the other places visited dealt only with city streets; and Mr. Cooley's report on Wayne County roads, while brief, is so comprehensive as to form what may almost be called a classic on the subject. In his judgment most of the longitudinal cracks which developed in the earlier construction were due largely to insufficient rolling of the foundation.

This investigation included interviews with a large number of citizens as to the objections, if any, to concrete roads. It is reported that but one farmer

was found who objected, for the stated reason that the concrete was hard on his horses' hoofs; he admitted, however, that a team would draw twice the load they could haul over the previous roads, and that his land had increased in value from approximately \$140 per acre to \$250 per acre.

In making his recommendation to the Winona County Commissioners, Mr. Cooley said:

"After a thorough study of the local situation and a very close examination of previous work in other localities, I have come to the conclusion that concrete roadways are not only feasible, but are the most practical style of construction for permanent highways.

"Concrete roads are dustless and are capable of transporting twice the loads with the same motive power that could be hauled over gravel or earth roads, and for pleasure vehicles cannot be excelled, as they are absolutely free from jolts and ruts. There is also the advantage that they require no maintenance, and it is a well known fact that lack of maintenance is the cause of failure of nearly all of our improved roads."

Mr. Cooley also recommended the use of concrete for the State Rural Highways, except in the extreme northern part of the State. As a result of the investigation and report Winona County has adopted this material for its entire system of county roads, and a considerable mileage was constructed during 1913; a stretch of considerable length is being built out of

Minneapolis in Hennepin County, and preparations are being made for a large mileage of concrete roads to be built in various counties during 1914. Mr. Cooley thinks that a mixture consisting of one part cement, two parts good sharp sand and four parts gravel ranging in size from one quarter inch to one inch will be entirely satisfactory; he lays great stress, however, on first-class, intelligent workmanship.

Before the Illinois State Aid Road Law was enacted, Mr. A. N. Johnson, State Highway Engineer, made a careful study of the needs of his State. He established a traffic census to determine the relative volumes of travel, and worked out, by a perfectly clear method of addition and subtraction, the basic principle that nearly eighty-five per cent of the traffic of his State goes over approximately fifteen per cent of the highways. This principle is recognized in the new law as representing practically the mileage that is to be improved with the aid of State funds.

After investigating the Wayne County concrete roads, and considering them in connection with the necessities of the travel in his own State, present and prospective, Mr. Johnson, in a somewhat elaborate argument, stated it as his belief that most of the main roads of Illinois would have to be built of either brick or concrete; and that by reason of its less first cost, the great majority of the mileage would be built of concrete. During the season of 1913 a considerable mileage of concrete roads were built in the different counties of the State; but as

most of the season was taken up with the work of getting the new highway law into operation, the amount was trifling as compared with the amount which will be done in this and subsequent years.

The fact that under the Illinois law the county, which pays half the cost of construction, pays no part of the maintenance, will naturally lead the State Highway Department to insist on a type of construction which will require as small an expenditure for maintenance as possible. And as the demand for improvement is certain to be far in excess of the appropriations, it is probable that Mr. Johnson's views on the subject will be put into practice extensively.

A careful study of the principles involved brings out very forcibly some important facts. To be satisfactory, a concrete road must be built on a thoroughly drained and compacted foundation. It must have expansion joints about every twenty-five feet. It must either be "broomed," or treated with bituminous material and sand, to prevent it from being slippery; and the concrete must be mixed and laid by men who know how.

As a concrete road is nearly level, the travel does not seek a single track in the center, but spreads over the width of the roadway. It is hard and smooth, requires no repairs, and is generally satisfactory for all kinds of travel. Its greatly extended use seems as certain to be one of the primary factors of highway economies as automobiles have been in the economies of transportation.

A Simple Method of Counting Alpha and Beta Particles*

Each Particle Registers Itself Automatically on a Photographic Record

By Prof. H. Geiger

SEVERAL years ago Rutherford and Geiger described a method of counting the alpha particles emitted by radioactive substances. The apparatus was so arranged that a small portion of the alpha particles flowing from the source passed through a mica window into a chamber filled with gas at low pressure. Each particle produced a small number of ions, whose motion was so greatly accelerated by a strong electric field that each of them produced some thousands of new ions by its collisions with gas molecules. This multiplication of the primary effect made it possible to demonstrate, by means of an electrometer, the entrance of an individual alpha particle. The string electrometer is best for this purpose, because the string moves and comes to rest so quickly that the deflection caused by every alpha particle can be registered distinctly by photography, even when 2,000 particles enter the ionizing chamber every minute.

With this apparatus the multiplication of the primary effect was limited by the occurrence of spark discharges when the potential was raised too high. For the same reason this method proved useless for counting the beta particles, which have comparatively little ionizing power.

I shall now describe a very simple and sensitive method of counting both beta and alpha particles by means of the discharges which they cause to flow from neighboring electrified points. The apparatus is indicated in the accompanying sketch. A brass tube A, about three fourths inch wide, is closed at one end by an ebonite plug E, through which a wire D, terminating in a fine point, passes axially. The point is about one third inch distant from the plate B, which nearly closes the other end of the tube, but has a central perforation through which the alpha and beta rays are admitted. The tube A is charged to a positive potential of about 1,200 volts and the axial wire is connected with a string electrometer, which is connected to earth through a liquid resistance that permits each charge communicated by the entrance of an alpha or beta particle to escape in a fraction of a second.

In air at atmospheric pressure a potential of 1,200 volts is usually sufficient to cause a discharge from the point on the entrance of each single alpha or beta particle. The quantity of electricity that passes in such a discharge is very considerable, producing, in a string electrometer of 10 centimeters capacity, deflections that correspond to potentials of 10 to 20 volts. As this quantity is nearly one electrostatic unit, although each beta particle produces only about 100 ions, each charged with 4.7×10^{18} electrostatic units, the primary effect of a beta particle is multiplied by ten million.

The efficiency of the apparatus depends chiefly on the goodness of the electrified point. The diameter of the tube and the distance of the point from the inlet may be varied within wide limits. A bad point gives

rise, usually at potentials of less than 1,000 volts, to spontaneous discharges, which are manifested either by very rapid quivering of the thread or by large single deflections. A good point responds energetically to the rays at a potential of 1,000 volts, but remains absolutely motionless in the absence of rays. It is characteristic also of a good point that the potential can be varied greatly without essentially affecting the action of the apparatus. The best points yet produced

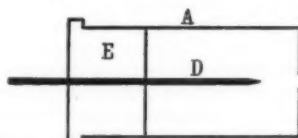


Fig. 1.—Diagram of apparatus employed.

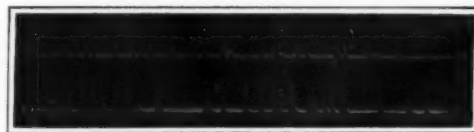


Fig. 2.—Photographic record of beta rays (upper curve) and of alpha rays (lower curve).

reached to alpha and beta rays at all potentials between 1,020 and 1,840 volts, but did not discharge spontaneously except at still higher potentials. Such points are seldom obtained and their range of sensitivity usually diminishes rapidly. It is quite sufficient for reliable working of the apparatus if it responds to alpha and beta rays within a potential range of a few hundred volts and does not discharge frequently in the absence of the rays. It is impossible to prevent an occasional discharge, caused by radioactivity of the air and the walls of the vessel. With various tubes used in these experiments the number of such discharges ranged from one half to two per minute.

It is impossible to give definite rules for the production of a good point. The best method is to grind a sewing needle to a slender point by means of an oilstone and a strop, examining it with a microscope from time to time, and to clean it with alcohol before mounting it in the apparatus, as indicated in the diagram.

Any tendency to spontaneous discharge can generally

Potential in Volts.	Alpha Rays.		Beta Rays.	
	Number of Particles Observed per Minute.	Average Deflection. (millimeters)	Number of Particles Observed per Minute.	Average Deflection. (millimeters)
1,100	45.8	5	23.4	2
1,180	54.0	10	33.4	5
1,260	65.7	20	41.5	10
1,340	56.7	20	50.5	20
1,420	49.7	25	51.5	20
1,500	55.0	25	52.5	25
1,580	55.0	25		

*Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from the *Proceedings of the German Physical Society*.

be cured by heating the needle cautiously in a Bunsen flame or by causing an electric current to flow for a considerable time from the point into the gas of the ionizing tube.

Gorton and Washing observed several years ago, in their measurements of the minimum potential of spark discharges, that the behavior of a point is often greatly altered by such treatment. In general the minimum potential of discharge is made higher, but it can be reduced temporarily to its normal value by ultra-violet or radium rays. This agrees entirely with my experience with the apparatus described above, which is so sensitive that a single alpha or beta particle temporarily lowers the artificially heightened minimum potential of discharge.

Some results obtained with an apparatus of the dimensions of the one shown in the diagram are given in the accompanying table. The alpha rays were emitted by polonium, the beta rays by radium E. We see that the point responded to alpha rays at all potentials between 1,100 to 1,580 volts, and that at potentials above 1,180 volts the number of deflections observed remained constant within the limits of errors of observation. Spontaneous discharges began to occur at potentials higher than 1,580 volts. With beta rays the number of deflections observed and particles detected per minute did not become constant until the potential of 1,420 volts was attained. At a given potential the average deflection was somewhat smaller for beta than for alpha rays, but the deflections were not proportional to the ionizing powers of the two rays. A deflection of one millimeter corresponds approximately to a potential of one volt. The radioactive substances were about one inch distant from the aperture, which had a diameter of one twentieth inch. As the diameter of the substance was several times greater than this, the entering beam of rays was very divergent, and with the beta rays the divergence was increased by the strong dispersion which these rays undergo in air. As those beta rays that enter the apparatus very obliquely at low potentials are unable to produce discharges from the point, it is easy to understand why the number of beta particles observed at low potentials was too small. Alpha particles are able to cause discharges, even when the particles enter very obliquely. For quantitative measurements, of course, the apparatus should be so arranged that the entering rays are nearly or quite parallel.

The experiments led to the conclusion that the polonium preparation emitted 4,000 alpha particles per second. This result agrees very well with the value derived from ionization measurements. It was proved, also, that the number of beta particles observed was proportional to the activity of the preparation.

This apparatus works very well even with weak radioactive substances. In this case it is best to use a large aperture, covered with thin aluminium foil. When a lump of pitchblend is placed near the foil the

alpha rays produce lively movement of the electrometer string. By interposing a sheet of paper the alpha rays are cut off, but the beta rays continue to affect the instrument, and the number of beta particles thus detected is quite large, for the particles come from the interior, as well as from the surface, of the pitch-

blend. Even the presence of gamma rays can be detected by interposing a sheet of lead one twelfth inch thick. The deflections then observed are caused by secondary beta rays generated by the gamma rays. The deflection and dispersion of beta rays can be demonstrated by similar simple experiments. In general, the

apparatus appears to furnish a simple means of studying the behavior of alpha and beta rays in various conditions. Experiments in this field have been undertaken in the Physikalisches-Technische Reichsanstalt, where the preliminary experiments described above were made.

The Manufacture and Uses of Blaugas*

Compressed and Liquefied Oilgas for Transportation in Cylinders

By Dr. Hugo Lieber

WILLIAM MURDOCH'S invention, in 1792, of a process for the manufacture of an illuminating gas, and the first establishment of a commercial gas plant in Birmingham, ten years later, was destined to be rapidly developed and perfected, so that it soon became a commercial necessity. However, one of the disadvantages of this invention was the fact that it required a considerable investment of capital for the manufacturing plant and its maintenance, and especially for the equipment of gas mains required to conduct the gas to the consumer. Therefore, it was soon recognized that a gas factory could be commercially and successfully operated only in such districts which were thickly populated, and where a large number of customers could be connected with the gas mains and thus be made consumers of this commodity.

The great advantages derived from the use of gas were soon recognized, and created a considerable demand for it, but owing to the limitations of a supply of gas to the territory traversed by the gas mains, and as beyond reach of these there was soon created a great and constantly growing demand for this commodity, many attempts were made to fill this demand.

These experiments resulted in various inventions of more or less value, having for their object the production of a compressed or condensed gas in such form that it would be commercially transportable beyond the reach of the gas mains.

In the experiments conducted by various investigators, coal gas as well as oil gas was used, but attempts to produce a commercially condensed and transportable coal gas were soon abandoned in favor of oil gas on account of the higher calorific value of the latter. The compressed oil gas is to-day still used very extensively, especially for lighting of railroads, buoys, light-houses, etc.

The compressing and commercially adopting of such compressed oil gas was successfully done especially by Pintsch, and with such compressed oil gas is usually identified the name of Pintsch owing to the great introduction of the Pintsch system throughout the world, and such compressed oil gas is usually known as Pintsch gas.

Under the Pintsch system, the oil is distilled at fairly high temperatures (900 deg. to 1,000 deg. Cent.) so as to produce as large an amount of fixed gases as possible. These fixed gases are subjected to a pressure ranging from 5 to 16 atmospheres, in the United States 6 atmospheres being the prevailing pressure. As under the Pintsch system, after distillation and compression, certain of the hydro-carbons are liquefied, these have to be removed, and only the remaining gaseous compressed hydro-carbons are permitted to enter the shipping containers.

A German chemist, Herman Blau, succeeded in making a great improvement in the production of a transportable compressed oil gas. He compressed oil gas to such a degree that the bulk of it was liquefied. The process employed by Blau is, in brief, as follows:

In the original process, gas oil is conducted into the retorts just as in the manufacture of Pintsch or other oil gas, and is vaporized and decomposed in these retorts under a temperature of about 550 deg. Cent. to 600 deg. Cent. This low temperature is employed in order to prevent the production of a large percentage of fixed gases, as contrary to the heretofore existing principle it was the desire of Blau to produce as large a quantity of the coereble hydro-carbons and as small a quantity of the permanent gases as possible. After the oil has thus been distilled, the gas obtained is conducted in the usual manner through hydraulic mains, coolers, cleaners and scrubbers in order to remove the tar which these gases contain. After this, the gas is purified of its chemical impurities by being forced through chemical cleansing agents, where especially sulphide of hydrogen and carbon dioxide, etc., are removed. This being completed, the gas is conducted in the usual manner into large gas holders for storage purposes. With the exception of the difference in the temperatures employed in the distillation process, the Blau process up to this point does not vary materially from any of the other well-known processes of oil gas distillation employed heretofore.

Since its first introduction, the Blau process has been

* Reproduced from *Metalurgical and Chemical Engineering*.

very materially and rapidly improved from time to time, these improvements having for their object the production of a better quality or a drier gas, and also the greater yield from a certain quantity of oil. In the original process as employed by Blau, the gas from the holder was drawn into a cooler where, under a suitable process, it was cooled considerably below zero in order to liquefy and discard at this stage certain of the coereble hydro-carbons which, in the finished product, were not desired; that is, such hydro-carbons which under normal pressure and temperature would again liquefy.

Under the new process, as it is employed in the various Blaugas factories at the present time, this preliminary cooling has been discarded. The gas is drawn directly from the holder into the compressor, which is usually a three-stage or four-stage compressor. The liquefying and discarding of those coereble hydro-carbons which are not desired in the final product now takes place in the first and second stage of the compressor, and the balance of the gas passes on into the third and eventually the fourth stage, where the gas is compressed up to 100 atmospheres. During all stages of the compression, water is injected into the compressing chambers for lubricating and cooling purposes. The water which is carried over after the final compression is separated from the liquefied hydro-carbons after the last stage of compression, and is then withdrawn from these by a suitable device. The refuse tar obtained from the cooled and scrubbed gases is collected in proper receptacles, and from there is pumped into tanks from where it flows by its own gravity to the retorts where, with compressed air or steam, it is sprayed under the retorts, and is thus used to supply all the heat required for these retorts.

As in the course of the manufacture, and during the distillation of the oil, a certain amount of permanent gases have been produced which the liquefied hydro-carbons have been unable to absorb, these permanent gases are conducted into large cylinders from which, by means of proper reducing and regulating valves, they are conducted into the engine, where they produce all the power which is needed in a Blaugas plant.

The whole Blaugas process, as it is now employed, is so minutely worked out that but a very slight excess of tar and permanent gases is obtained beyond the quantities required for heating and power purposes. The final product consisting of liquefied hydro-carbons, and absorbed therein or dissolved thereby non-liquefied hydro-carbons, is of such composition that this whole aggregate remains a liquid as long as it is under the pressure employed in the process, but these liquefied hydro-carbons at once become converted into a gaseous aggregate if the pressure is reduced to approximately atmospheric pressure. These liquefied hydro-carbons are conducted into suitable steel cylinders or bottles for transportation purposes.

Under the compression of 100 atmospheres, the oil gas is reduced to 1/400 of its volume, the gas so obtained being of a specific gravity which is approximately the same as that of atmospheric air. One liter, that is, 1.246 grammes of Blaugas at 0 deg. Cent. and 760 millimeters barometer contains 1.042 grammes carbon and 0.204 gramme hydrogen. This gas has a calorific value of about 1,800 B.t.u. per cubic foot, or approximately three times the heat value of ordinary city gas.

The explosive range of Blaugas is lower than that of any other commercial illuminating gas, which the following table will show:

	From	To	Explosive Range
Coal Gas.....	6.33% gas 93.67% air	19.33% gas 80.67% air	13.0%
Acetylene.....	2.00% gas 98.00% air	49.00% gas 51.00% air	47.0%
Hydrogen.....	9.50% gas 90.50% air	66.30% gas 33.70% air	56.8%
Blaugas.....	4.00% gas 96.00% air	8.00% gas 92.00% air	4.0%

As has been stated before, the heat value per cubic foot of Blaugas is about 1,800 B.t.u., whereas that of acetylene is 1,500 B.t.u. per cubic foot and of hydrogen 425 B.t.u. per cubic foot. As the volume of Blaugas is reduced to 1/400 under its compression, it requires much

smaller receptacles to transport a certain number of heat units with Blaugas than with any other gas.

Of the commercially transportable gases are to be considered acetylene, hydrogen and Blaugas, as Pintsch gas is a transportable gas in a limited sense only. Acetylene can be considered as a transportable gas only under the so-called "Acetylene Dissous" system. The following table will show the heat value per cubic foot, the container capacity, the weight of containers required for a given number of heat units, the number of containers required and the price per 100,000 B.t.u.:

	Hydrogen	Acetylene Dissous	Blaugas
Heat value, per cu. ft.....	425 B.t.u.	1,500 B.t.u.	1,800 B.t.u.
Contents of a container of 1 cu. ft. water capacity....	120 cu. ft.	100 cu. ft.	300 cu. ft.
Weight of containers required to transport a given quantity of heat units (for example 540,000 B.t.u.).....	1,060 lbs.	432 lbs.	100 lbs.
Number of containers required to ship 5,400,000 B.t.u.....	106	36	10
Price for 100,000 B.t.u.....	\$1.41	\$1.00	\$0.44

Hydrogen, per cu. ft., 3/5 cent.
Acetylene Dissous, per cu. ft., 1 1/2 cents.
Blaugas, per cu. ft., 4/5 cent.

Blaugas is transported in steel cylinders of various dimensions ranging in size (water capacity contents) of from 1/4 liter to about 100 liters. The size mostly used is a cylinder with a water capacity of about 27 liters, or about 1 cubic foot. This cylinder when properly filled contains about 20 pounds of Blaugas, which will become converted into about 250 cubic feet of expanded gas when the pressure is released. As Blaugas contains no carbon monoxide, it is a non-poisonous gas.

Blaugas is used mostly in such districts where no gas is supplied from a central gas plant through ordinary mains, but it is also used very extensively in districts where city gas is supplied, especially for steel and cast-iron welding and cutting, brazing, soldering, for laboratories and such purposes where a uniform gas with high heat units is essential.

In districts where gas is not supplied through mains or through a central plant, Blaugas is used for all purposes where otherwise city gas is used, namely, for illuminating, cooking, ironing, heating, and similar purposes.

The cylinders are attached by means of a reducing valve to a small expansion tank, and from there the gas is conducted into the pipe line by a pressure regulator. As Blaugas is under a high pressure when delivered to the consumer, it is a very simple matter to produce so-called pressure gas wherever it is required, pressure gas being very desirable for the production of brilliant illumination, one c.b.f. of Blaugas producing 80 candles in an incandescent Welsbach burner.

The first Blaugas factory was erected in Augsburg, Germany. This was rapidly followed by other factories in Budapest, Copenhagen, Bucharest, St. Petersburg, and Hook von Holland. In the United States, at the present time, there are factories in Long Island City, St. Paul, Kansas City, Omaha, and Portland, Me. There are a number of factories now in course of construction.

The Invention of Celluloid*

By L. H. Baekeland, Ph.D.

NEVER has the Perkin Medal been better awarded than to John Wesley Hyatt. He created a distinctly American industry, chemical in its very essence, although the inventor never claimed to be a chemist. He not only invented the fundamental principle on which this important industry is based, but he gave his fertile inventive genius and the better part of his life to the development of the many details which built up the technique of celluloid.

The technique of celluloid is strikingly different from that of rubber and all other plastics. This explains why rubber technologists ordinarily fail when they attempt celluloid manufacturing. It provides an excuse why the hard rubber companies of this country failed to see the coming importance of celluloid when the new material was offered to them.

* Reprinted from the *Journal of Industrial and Engineering Chemistry*, Vol. 6, No. 2, page 90. February, 1914.

I believe it was Rudyard Kipling who, in one of his writings, refers to a fisherman who was specially successful because "he could think as a cod-fish would think." I have observed in meeting celluloid or rubber manufacturers that the former cannot think but "celluloid," and the latter "rubber," and are much at sea when they are confronted with the technique of a new plastic.

I may mention here, from conversations with the inventor himself, that celluloid and the celluloid industry with all that it implies, after all meant merely a big parenthesis in the life of Hyatt in his quest of a perfect billiard ball which would replace the expensive ivory article. This is so true that even during his later years, when he is well in the seventies, he has spent considerable time in the study of other plastics in his effort to still further perfect billiard balls. Celluloid and the celluloid industry are by no means the only inventions which Hyatt has to his credit; the famous Hyatt Roller Bearing which has developed into a large and successful manufacturing enterprise, his methods of water purification (with Isaiah S. Hyatt), his process for crushing sugar cane and his many other patents testify to the abundance as well as the diversity of his inventive achievements.

The invention of celluloid is an excellent example of how sometimes it is a real advantage for a man of genius not "to know too much"; not to be hampered by too much book knowledge if the latter tends to petrify the mind into a too one-sided point of view. In all his work Hyatt's keen observing mind was his sole guide. He tried things for himself. He did not rely overmuch on what others told him to be the facts, or on what was written in books. He wanted to be his own "authority."

He found by experience that there are many things printed in books and chemical treatises "that ain't so." He thus discovered the important fact, on which the whole celluloid industry is based, that a mixture of nitrocellulose, camphor and a small amount of alcohol, when properly prepared, becomes thermoplastic. In other words, it becomes soft when treated, can be molded in a hydraulic press, and after cooling to ordinary atmospheric pressure, it becomes again hard and strong.

His predecessors all used nitrocellulose in presence of relatively large amounts of solvents, and used a solution, or a relatively soft mass, from which the solvents were left to evaporate. This not only meant a considerable loss of solvents, but restricted enormously many possible technical applications. The mass shrunk in the act of drying and rapid molding was impractical, if not totally impossible.

Some of his predecessors had even used camphor in their solutions, although Hyatt knew nothing about this until it came out later in his patent suits. But his predecessors had used camphor merely as any other solvent. They had failed to observe or to grasp the great technical importance of the fact that camphor could make a solid solution with nitrocellulose and produce a thermoplastic mass.

This seemingly simple observation might have left very little imprint on any other but the actively constructive mind of a Hyatt. He saw right away that from that moment on he could employ purely mechanical means for molding rapidly and effectively and develop the technique of nitrocellulose plastics for purposes never dreamed of before. The principle was simple and the available methods seemed simple enough. But, as usual, when one tries a process commercially it was found that there were endless details which conspired to render the industrial and commercial development a far more difficult problem than the mere discovery of the new principle in the laboratory. Here the whole problem might have suffered shipwreck in the hands of any other man than Hyatt. The whole technique of celluloid was then developed painstakingly by him in all its endless details. Special machinery was invented, new methods were conceived. All this is shown by the numerous subsequent patents.

It is an axiom that the test of a valuable invention is that it should be infringed or attacked by those whose thinking cells are passive until some inventor arouses them out of their mental drowsiness.

Hyatt, in his patent suits, had plenty of experience of the kind. Fortunately, his financial backers could afford to defend his rights in the absurdly long and expensive patent litigation, which is a proverbial characteristic of the inefficient administration of the patent laws of this country.

I believe it was George Westinghouse who reminded us that every successful invention passes through three stages: The first, when it is said: "Such a thing is absurd or impossible." The second stage, after the patent descriptions have become public and have given others the means to imitate and try to find loopholes in the patent claims, begins when it is said: "The thing is not new." And finally, after the usefulness of the invention has become so obvious and the details connected therewith have penetrated through the hard skulls of the lawyers, then it sounds: "There is no invention at all."

Hyatt's invention went through every one of these

three stages, and were it not for the Perkin Medal many of us might have forgotten that there ever was such a man as Hyatt and that there was a time when celluloid did not exist, or involved very difficult problems.

His patents were assailed on the ground that others before him had used solvents and camphor in conjunction with nitrocellulose, but it was studiously omitted that his predecessors had used these ingredients under entirely different conditions for entirely different purposes, and could not produce in that way Hyatt's valuable technical effect. The very solvents which proved a bar to any important applications for molded plastics Hyatt did away with when he conceived his thermoplastic mass.

Some of the early drawbacks in the technical applications of Hyatt's discovery were none other than chemical experts with which his financial backers surrounded him. Hyatt knew no chemistry, but he knew well-observed facts intimately connected with the details of the work he had undertaken. His knowledge of nitrocellulose was obtained piecemeal by his own experimenting. Facts found in books he accepted only after he had verified them. It so happened that he frequently noticed that printed statements did not agree with his own observations. One of the chemical experts insisted that "cellulose was cellulose," regardless of the source of supply, provided it was sufficiently purified, and that nitrocellulose made from any kind of pure cellulose had the same properties. Hyatt knew better when he found that the article made from ramie, the strongest and most expensive cellulose, was incomparably superior to that obtained from cheap cotton or cheap pulp cellulose.

Some chemical experts also made the positive statement to his backers that his process would surely lead to terrific explosion because he was heating in a hot press nothing less than gun cotton, which was known to be a violent explosive. Though Hyatt state that he had been using his process for quite a time and still was alive, it was objected that this was simply due to sheer good luck which would cease at some time; if ever it happened that by accident or carelessness the heat in his presses rose a little higher, a violent explosion was bound to occur, and this would be the end of the celluloid industry. These arguments were not by any means without logic. At that time it is doubtful whether any chemist who knew the chemical properties of nitrocellulose would not have thought it the height of folly to heat this substance under pressure.

Hyatt not being a chemist, preferred to try and see for himself what would occur. He took a good-sized block of celluloid and heated it in the hydraulic press at a temperature far superior to the relatively low temperatures he was using in practice. He tells me that he was sufficiently impressed by all the threatening talk of the chemical experts to screen himself from the press by means of several thicknesses of cross boards behind which he could peep on and see what was going to occur. After the temperature rose to the point when the celluloid began to be destroyed, the block started sizzling on account of the emission of gaseous products. But he continued the experiment until he made sure that nothing worse occurred than to spoil the material.

Automatic Stabilizers*

It is undeniable that pilots are opposed to the use of automatic stabilizers on aeroplanes, and as they do not usually give any reasons for their opposition, the inventors have good cause for accusing them of hindering progress. And yet the pilots are not far wrong. If they do act thus from prudence nobody will blame them, for although experiments with a badly designed stabilizer may enlighten the inventor as to the defects of his device, they will possibly be carried out at the expense of the aviator's safety.

But there is another cause other than justified caution for the attitude of the pilots. All the stabilizers which I have seen up to the present have been founded on two hypotheses. Firstly, that the conditions for stability of an aeroplane, its position in the air, its speed, etc., are invariable during flight. Secondly, that the maneuvers to be carried out to bring the machine back to its stable equilibrium depend solely and directly on the disturbance which occurred during the flight.

But that is not even all. The conditions for stability of an aeroplane vary every instant with the atmospheric conditions. Having its symmetrical plane vertical, its flight path horizontal, and a constant speed, constitute the stable state of an aeroplane for certain atmospheric conditions only, i. e., absence of wind or the existence of an absolute constant wind in the region where the aeroplane flies. But these atmospheric conditions are absolutely exceptional, and to each variation of these conditions corresponds a variation of the stable equilibrium. Sometimes it is best to bank to the right, sometimes, on the other hand, it is advisable to bank to the left. Sometimes the pilot must fly *cabré* and sometimes he must fly

piqué, or again it may be advisable to increase the speed or to diminish it, and he constantly has to combine all these maneuvers. In other words, there does not exist a fixed stable equilibrium, but there is one corresponding to each particular atmospheric condition. The making of a pilot consists precisely in developing in him that sense of the air which will, at any instant, make him instinctively choose the best attitude. Up to the present it does not seem that this attitude can be determined.

A lengthy experience has taught me that the proper maneuver to execute in order to right a machine does not depend directly on the disturbance itself, but more on the cause of the disturbance, so that for two precisely identical attitudes taken by the same machine through different causes, the maneuver required to right the machine differs also. The word "remous," which has often been abused for the purpose of masking our ignorance of the matter itself, serves to denote every variation in the movement of the atmosphere, but these variations may be caused either by obstacles on the ground, by local calorific phenomena, by the electric state of certain regions of the air, or by other causes which the future may reveal, and the required maneuver varies in each case. How can the inert matter which constitutes the automatic stabilizer discern the difference in causes of the identical phenomena? And it is very often a question of life or death. Only a thinking and intelligent being—one acts more often from intuition than from reflection—can discern the difference and consequently modify the action. A thinking, feeling, acting organ—what is it but man?

Besides, it should be noted that an automatic stabilizer, since it is unable to perceive the cause of the disturbance, and is also unable to foresee or anticipate it, does not begin to work until after the disturbance in the path of the aeroplane has existed for some time. It should begin working beforehand in order to diminish the anticipated effect of the cause, and furnish the maximum of correction before the disturbance has reached its maximum. When a boat approaches a wave, does the pilot wait till his craft is careened by the wave before applying his maximum control? No; he measures with his eye the advancing wave, gives his boat the most favorable position, and does almost all his controlling before reaching the top of the wave, that is to say, at the moment when the *denivellation*—the variation in water level—attains its maximum. The same should be done in the air. But, because the air wave is not visible to the eye, our theorists do not see it, and, having never felt it, they deny the pilot, who does feel it, the right to know better than they themselves what is the matter. They consequently impose upon him the use of instruments which, provided they do not work wrongly, certainly have little effect. The result hereof has, moreover, been proved experimentally. Recently at Juvisy a machine fitted with an automatic stabilizer was flying simultaneously with other machines not so equipped, and all the eye-witnesses can testify that, although the machine fitted with the stabilizer did not require any control by the pilot, it was tossed about much more than were the other machines. How would it have fared in a gale?

If it is advisable to give the aeroplane such a form that it flies normally in a position which is comfortable for the pilot—with the head upward most of the time—it is indispensable to leave all the control organs at the disposal of the pilot exclusively.

Finally, the start, and especially the landing, involve very delicate maneuvers when the conditions for the equilibrium of the machine, as it changes its means of support, alter radically and rapidly. These maneuvers demand a certain judgment; it is a matter of importance, it will be agreed, whether the flight path becomes parallel to the ground at 10 centimeters or at 10 meters, or that the path of flight meets the ground before becoming parallel to it; and it will also be agreed that the most favorable moment for flattening out is of very short duration in aeroplanes traveling at a speed of 20, 30 or 50 meters per second. Also, and precisely on account of the lack of sentence, the automatic stabilizers must be disconnected when in the vicinity of the ground.

Also when the machine is far from the ground, and when its attitude is of more consequence for the comfort than for the safety of the pilot—perhaps even for Pégoud, although he finds it very comfortable to fly head down—the most tangible effect of the automatic stabilizer is to increase the fatigue of the pilot and the machine by enlarging the disturbances. When close to the ground—that is to say, when the attitude of the machine is of vital importance—the stabilizer must be disconnected.

Why then be bothered with such impediments? The management of an aeroplane is not a purely mechanical problem, the fixed principles of which allow of attributing an invariable and automatic solution; it is an ever-changing struggle with a very capricious and changeable element—the air; and to follow such an opponent in his feints and tricks requires more than raw material, it requires an organ with alert intelligence, supple and quick, with instantaneous decision—it requires a pilot.

* Translation of an article by *Flight* from Bulletin mensuel de l'A. G. A. F. The author is Captain Bellenger, a well-known French army officer.



Constructing a spur levee to keep the river from cutting across.

Curbing the Mississippi

Spending \$500,000 to Prevent the River from Cutting Off Thirty Miles of Itself

By James R. Crowe



Playing the hose on banks to give them the required slope.

THERE is a horseshoe loop in the Mississippi River near the Tennessee-Kentucky State line, 30 miles around but less than a mile across the heel. The Government is spending about \$500,000 to prevent a cut-off. If left alone, the next high water will cut through this narrow neck of land, and Hickman, Ky., will be 30 miles closer to Tiptonville, Tenn. The United States engineers, however, are literally as well as figuratively curbing the restless river in order to prevent the decapitation of the little head of land.

To the casual observer, it seems that the engineers have very little to occupy their time to undertake such a thing, and that they are bent on squandering the appropriation set aside by Congress for the improvement of the river. The question of why they should attempt to thwart the tendency of the river to simplify and to straighten out its tortuous channel naturally arises. The reason is not that such an event would donate about 10

the river might be shorter and straighter. Its present length, which varies slightly from year to year, represents, however, a balance between the forces involved.

It is a well-known fact that when the river cuts through one bend it sets to work at once in making another just as long. The revetment work at Slough Neck is based on this proposition. There is a difference of six feet in the level of the river on the two sides of the narrow neck.

If the river is allowed to cut through the neck, the swift current will attack with terrific fury the Missouri bank near Point Pleasant. Not only would it destroy thousands of acres of fertile cultivated land, but in a short time it would undermine the levee which is only a short distance inland and thereby entail an expenditure many times the cost of the revetment work now being placed.

The only successful method of curbing the Mississippi River is by means of mattresses woven from willow saplings and held in place with rock ballast. The mats

man who owned a farm on the outside of the loop used to guard the neck of the bend with a shotgun to prevent the other fellow from plowing a furrow across when the river was up.

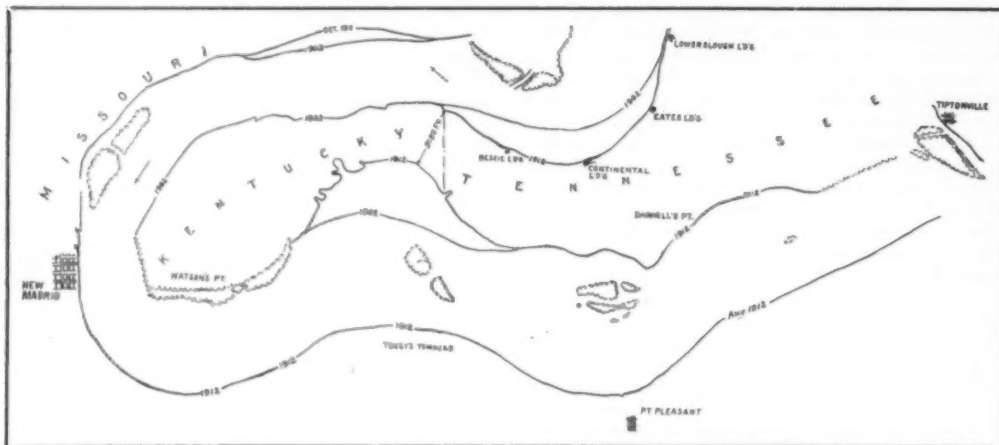
Cut-offs sometimes play peculiar practical jokes on the river towns. Frequently a town with a flourishing steamboat trade wakes up and finds itself several miles off the main river. Vicksburg is now five miles up Centennial Lake. The river a few years ago threatened to leave Memphis high and dry. A few years before that the same city had to make a desperate fight to keep from being washed away. The town of Delta is now several miles below Vicksburg, but before the war it used to be three miles above Vicksburg. The town itself has remained stationary, but the river has migrated.

It is not always a certainty that the Mississippi River flows down-stream. At Island Thirty-seven, the river now flows in the opposite direction from its former course in the same channel, for a distance of two miles.

A Government engineer who has spent a large part of his life surveying the river tells of a peculiar state of affairs. It is possible, he says, to take a light canoe at Greenville, and to drift 40 miles up the river by making three portages. The river there makes a series of horseshoe bends. The man drifts down the river about 10 miles below the city until he comes to a narrow neck of land. He carries his canoe across and drifts back in the opposite direction on the upper side of the bend almost to Greenville to another neck, and taking his canoe on his back he gains crosses over and floats west. He lifts his canoe out again, and when he puts it back in the river again, after the portage, he finds himself above Island Eighty-two, which is 40 miles up the river from where he started.

Study of Purified Water

An interesting study of the properties of purified substances is described in a recent issue of the Chemical Society's Journal, vol. ciii., p. 2060, in a paper published by Prof. H. B. Baker jointly with Mr. L. H. Parker. Two years ago, at a meeting of the Faraday Society, an experiment was shown in which water prepared under special conditions acted much more slowly than ordinary distilled water on sodium amalgam. It was remarkable that this difference persisted even after a considerable amount of caustic soda had been formed; it was therefore not due to the non-conducting properties of the special water, and has now been traced to the "catalytic action" of traces of hydrogen peroxide. These are present in ordinary samples of water, and in water prepared from pure hydrogen and oxygen in presence of palladium, but are destroyed by distilling from metallic vessels and superheating the steam. One sample of water prepared in this way in a platinum apparatus had no perceptible action on sodium amalgam in three hours, and liberated only 0.1 cubic centimeter in four hours, 0.4 cubic centimeter in five hours, and 0.6 cubic centimeter in six hours. On the other hand, the addition of one part of hydrogen peroxide to 100,000 parts of another sample of water increased the amount of hydrogen liberated from 0 to 3.5 cubic centimeters in one hour, and 4.1 to 32.4 cubic centimeters in three hours, although it did not appreciably affect the conductivity of the water.—Nature.



The Mississippi at the bend, showing point, at Continental Landing, where it threatened to cut through.

square miles of the State of Kentucky to Missouri, nor is it because it would leave the flourishing river town of New Madrid about 15 miles inland. Neither is it because it would shorten the distance between Memphis and Cairo by 30 miles for the steamboats. The cut-off habit of the river is looked on with disapproval by the Government engineers. Instead of trying to help the river to become as straight as possible, on the contrary they are trying to persuade it to follow its present meanders.

The real reason is, that a cut-off increases the slope of the river so that it becomes an agent of destruction rather than an artery of commerce. They hope to make the channel permanent in one place. For such a vast volume of water flowing between soft alluvial banks, there is a certain slope which must be maintained. To disturb the balance between the strength of the banks and the slope of the river causes a greater strain on the bank somewhere than it can stand, and as a result the land is ripped and torn until the equilibrium is again restored. If the banks were made of stronger material or the slope between Cairo and New Orleans were less,

are held together with wire cables. Sometimes even these mats cannot resist the river, but are swept away.

In addition to curbing the river, the banks are sometimes paved. The purpose is to keep the river, when it is out of its banks, from undermining the mats from the land side. The banks are first given a gentle and uniform slope with a hydraulic grader, and this slope is paved with rough stones. The exposed points of the banks are frequently coated with a layer of concrete in addition. The hydraulic grader uses a stream of water from centrifugal pumps many times stronger than that of a fire hose, and it is said that it is impossible to cut the stream in two with an ax near the nozzle. The stream will tear a hole through a man if it hits him at short range.

It will also be necessary to build a spur levee at Slough Neck, as a kind of a backbone for the neck to keep the river from cutting across in spite of the revetment.

Cut-offs used to be made by every high water. They are less frequent now, on account of the revetments. They used to be encouraged by men who owned plantations which would be put on the river by a cut-off. The



Completed mat ready for ballast to be placed upon it.



Starting the mat. View showing willow and mooring barges.

Artificially Induced Pearl Production*

By H. Lyster Jameson, M.A., D.Sc., Ph.D.

THE studies of the last dozen years or so directed to the elucidation of the mechanism of pearl-production, and of the pathological conditions which induce or favor it, have made it increasingly clear that the production of a pearl is not, as was formerly largely believed, the direct result of the effort of the mollusc to cover over with nacre an irritating foreign body (e. g., a grain of sand or a parasite), but rather of the presence in the subcutaneous tissues of a portion of the shell-secreting epidermis, in the form of a closed sac, which need not necessarily be associated with any foreign body. The factors that determine the presence or otherwise of such an epidermal "island" seem to differ in different species of molluscs, and in the same species in different localities. The case in which the chain of causation is most fully known is that of the pearls formed through the agency of the trematode *Gymnophallus* in the common mussel, *Mytilus edulis*, worked out by the present writer in 1902 (*P.Z.S.*, 1902, vol. I, pages 140-166), in which case the mollusc normally surrounds the parasite, while still alive, with a closed sac composed of the outer shell-secreting epidermis; and this sac, on the death of the parasite, or on its migration to another part of the host, lays down concentric layers of the shell substance, so forming a pearl. The fact that *Gymnophallus* invariably becomes surrounded by such a sac, after settling down in the mussel, and that other parasites and foreign bodies do not normally share the same fate, pointed to the conclusion that the formation of the pearl-sac, and consequently of the pearl, is due to some peculiar or specific stimulation on the part of the parasite, and not to mere mechanical irritation, such as would arise from the presence of any foreign body. But the nature of this stimulation, whether mechanical (as e. g., by the parasite habitually carrying in with it a portion of the epidermis) or toxic (i. e., resulting from an abnormal growth of epidermal cells induced by some specific secretion of the parasite and comparable to the production of plant-galls), is a question which still awaits further investigation.

The artificial production of pearly excrescences, or blisters, on the interior of the shell, by introducing between the mantle and the shell beads or metal images, which become coated over with nacre, has long been practised by the Chinese, and has been developed into a flourishing industry by the Japanese, whose "culture pearls," formed over a core of mother-of-pearl, are now familiar objects in cheap European jewelry. The secret process devised by Linnaeus for producing pearls in

fresh-water mussels was analogous to these methods, though never commercially developed; and similar enterprises have been attempted in Burma and elsewhere. All these processes have, however, so far only resulted in the production of pearly excrescences, or blisters, on the shell; and the successes in the produc-

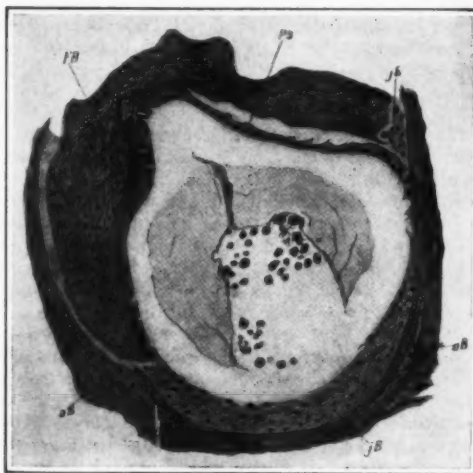


Fig. 1.—Section through an artificially produced pearl-sac in *Anodonta*. $\times 160$. The pearl-sac is not yet completely formed, the epidermal epithelium (*Pa*) being absent from one side of the cavity (at the bottom of the figure). Pearly substance, however, is already in process of formation. *aB*, autochthonous connective tissue; *FB*, transplanted connective tissue; *JB*, young transplanted connective tissue. Five days after the operation.

tion of free pearls in this manner, which have been claimed from time to time, have not been scientifically demonstrated. Recently, in Japan, Mr. Mikimoto is stated to have produced a few small free pearls by artificial means, but the method adopted has not been disclosed, and success on anything like a commercial scale has not been achieved.

The production of free pearls by mechanical treatment—not, of course, on a commercial scale as yet—has, however, recently been successfully accomplished by Dr. F. Alverdes, working under Prof. Korschelt at Marburg, and is described in a paper in the *Zoologischer Anzeiger* for September 12th of last year.¹ The method adopted by Dr. Alverdes was the introduction, by injection into the mantle-parenchyma, of fragments of the shell-secreting epidermis. The molluscs upon which he operated were the fresh-water pearl-mussel (*Margaritana margaritifera* L.), which is still fished for pearls in some of the rivers of Scotland and Ireland, the common pond-mussel (*Anodonta*) and the river-mussel (*Unio pictorum* L.).

The method of treatment was as follows: The shell was held open with a wedge, a portion of the mantle-margin was detached from the shell (to which it is normally bound by the reflected margin of the periostracum), and fragments of the outer shell-secreting epidermis of the mantle were scraped off with a knife; in other cases a small disk of tissue, containing both the shell-secreting epidermis and the ciliated lining of the mantle-cavity, was cut out. These fragments of epidermis, with the connective tissue which remained adherent to them, were then injected into the loose connective tissue of the mantle of the mussel.

After treatment the molluscs were returned to their native waters, where they were kept in suitable enclosures. They were killed, and examined at intervals ranging from 2 days to 27 weeks. The wound caused by the injection was quickly healed by the migration of wandering cells, to form a scar, leaving intact the introduced "island" of epidermis (see Figs. 1 to 3), with such connective tissue as happened to have remained attached to it. These "islands" did not, as might have been expected, fuse with and become indistinguishable from the autochthonous tissues, but remained sharply marked off from them throughout, and no actual concrescence between the transplanted and the autochthonous connective tissue seems to have taken place. Dr. Alverdes found that, when the injected epidermis came to lie with the free surfaces of the cells against the autochthonous connective tissue, it died in a short time. If, however, a fragment of epidermis found its way into one of the cavities which occur in the parenchyma

it survived, and spread out around the cavity as though endeavoring to cover over the exposed connective-tissue surface with epidermis, in a manner recalling that figured by the present writer in the developing trematode-sac in *Mytilus* (*loc. cit.*, Plate XIV, Figs. 2 and 3). Alverdes considers that the process here involved is not due to a multiplication of the epidermal cells by mitosis, but to a flattening out of the cells, mitotic figures first appearing after the cavity is completely lined with epidermis. By the growth of the epidermis around the cavity in the parenchyma a closed pearl-sac is formed; and then the growth therein of a pearl follows naturally from the normal secretion of this epidermis. If the space lined with epidermis is more or less spherical, so is the pearl; if it is irregular, a pearl of irregular shape results.

The growth of the pearl-sac takes place with remarkable rapidity, being completed in from 2 to 14 days. This point is of interest as helping to account for the great difficulty that has been experienced by all workers on the subject in searching for the earliest stages of pearl-sac development in nature.

Cysts were also formed by the ciliated epidermis which lines the mantle-cavity when successfully injected. It would be interesting to pursue experiments with this tissue, to ascertain whether these ciliated cells would retain their original characters or whether under any circumstances they are capable of giving rise, either by direct transformation or by cell-division, to shell-secreting epidermis.

The size of the pearls which Dr. Alverdes produced depended, in the first instance, on the sizes of the cavities into which the injected epidermal fragments found their way. They ranged from 30 μ to 1 millimeter in diameter. In some cases the secretion of pearly substance in the sac began a few days after the operation; in others it had not started after seven and a half weeks (see Fig. 3).

Quite apart from the interest which attaches to so important a step in the direction of the solution of the economic problem of artificial pearl-production and to the achievement of an end which has long been foreseen by zoologists, the theoretical value of these experiments is considerable, as adding one more link to the chain



Fig. 3.—Section through an artificially produced pearl-sac in *Unio*, in which a pearl has not yet begun to form. $\times 300$. Remains of dead cells are shown in the center of the epidermal sac. *FB*, transplanted connective tissue. Seven and a half weeks after the operation.

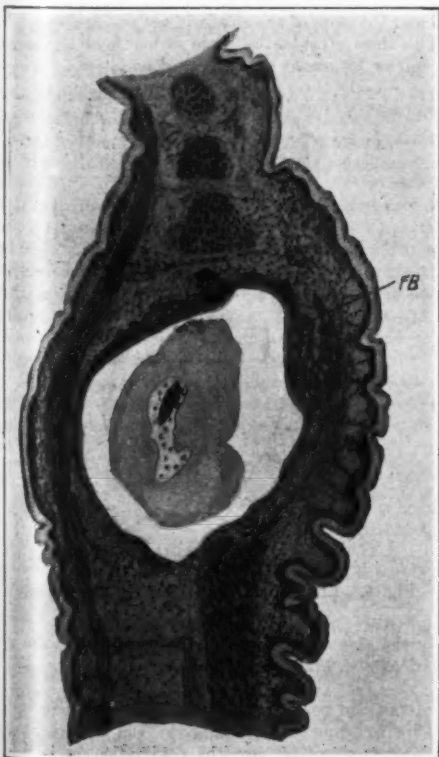


Fig. 2.—Section of an artificially produced pearl (decalced) about 1 millimeter in diameter *in situ* in the mantle of *Margaritana*. $\times 54$. A dark foreign "nucleus" accidentally introduced is seen in the center of the pearl. *FB*, transplanted connective tissues. Twenty-seven weeks after the operation.

¹ Versuche über die künstliche Erzeugung von Mantelperlen bei Süßwassermuscheln. *Zool. Anzeiger*, Bd. xlii, Nr. 10, 88, 441-458.

of evidence that goes to show that the real determining factors of pearl production are to be sought, not in the efforts of the mollusc to coat over with nacre any intrusive body, but in the presence in the sub-epidermal tissues of an island of epidermal tissue which may have arrived there as a result of purely mechanical processes, as in Dr. Alverdes' experiments, or of the specific action of a particular kind of parasite, as in the case of *Mytilus*, or, as is suggested by Rubbel's recent work on *Margaritana* and allied forms, from some obscure derangement of the normal shell-secreting mechanism. In the pearls produced by Alverdes a "nucleus" was only present when some foreign matter (e. g., quartz grains) was accidentally introduced along with the epidermis, or when cells, derived from the mollusc itself, became isolated in the lumen of the sac, and consequently embedded in the pearl.

Quantitative Colorimetric Analysis—II*

Its Theory, Laboratory Methods and Apparatus

By G. A. Shook

Continued from SCIENTIFIC AMERICAN SUPPLEMENT No. 1994, Page 179, March 21, 1914

THE USE OF SPECTROPHOTOMETERS.

WHENEVER white light, such as sunlight or the light from any incandescent solid, is passed through a prism, it is broken up or dispersed into a continuous band of colors which is known as the *spectrum* of white light.

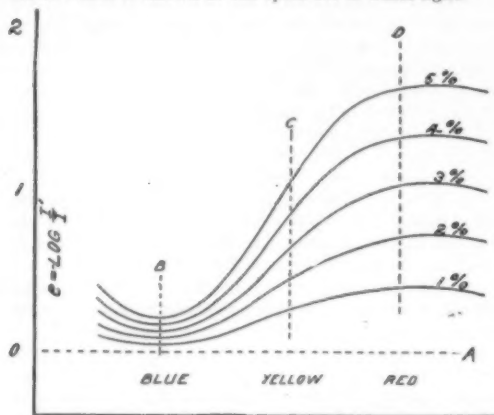


Fig. 1.—Absorption curves for a blue solution.

The spectrum of a gas consists of bright lines which are more or less well defined; for example, when a salt of sodium is vaporized it produces a yellow flame, and if this flame is examined by means of a small spectro-scope its spectrum is observed to consist of one bright yellow line.

If a colored solution, say copper sulphate, is placed before the slit of the spectro-scope we obtain the *absorption spectrum* of copper sulphate. The solution does not transmit simply one blue line, but to some degree all the colors, the blue region, of course, being the brightest. The intensity diminishes rapidly in the orange and yellow region and is relatively weak in the red region.

A cobalt solution, on the other hand, gives an absorption spectrum which is more intense in the red than in the blue.

In the case of most organic compounds, however, the intensity does not vary continuously from color to color, but the bands are more numerous and generally very much narrower than the bands observed in the spectrum of a simple solution like copper sulphate.

In the first article of this series, published in our issue of March 21, it is shown that the concentration of a solution is directly proportional to the logarithm of that fraction of light transmitted by unit layer of the solution, that is

$$\log(I/I_0) = kc$$

or

$$c = -A \log(I/I_0) = Ae \quad (1)$$

where I is the intensity of the incident light and I' the intensity of the transmitted light.

e is known as the *extinction coefficient* and A the *absorption ratio*. The concentration c will be expressed in per cent in all the calculations that follow. A 10 per cent solution here means that 10 grams of solute are dissolved in 100 cubic centimeters of solvent.

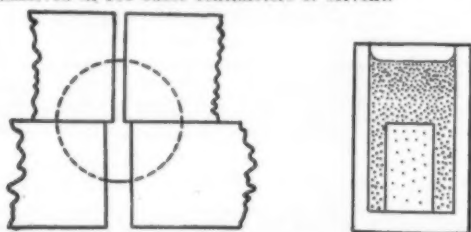


Fig. 4.—Symmetrical double slit.

Any notation may, of course, be used so long as one is consistent.

In many of the best instruments the intensity is controlled by means of a slit and the screw head which actuates the slit is divided into 100 divisions. When the head is turned to the 100 mark the slit is opened 1 millimeter. It will, therefore, be found convenient, in some cases, to express the fraction of the light transmitted, I'/I , in per cent.

Now we may write

$$e = -\log(I'/I) = \log I - \log I'$$

* Reproduced from Metallurgical and Chemical Engineering.

Suppose, for example, that 20 per cent of the incident light is transmitted through a unit layer of a solution, then

$$e = -\log 20/100 = \log 100 - \log 20 = 2 - 1.301 = 0.699$$

Therefore, whenever (I'/I) is expressed in per cent

$$e = 2 - \log I' \quad (2)$$

and

$$c = A e = A (2 - \log I') \quad (3)$$

These relations are only strictly true for homogeneous light, i. e., light of one color, so that in accurate work it is best to use a *spectro-colorimeter* or a *spectrophotometer* for the optical determination of concentrations.

In the spectro-colorimeter the light from the two containing vessels is rendered monochromatic either by means of a prism system or a number of monochromatic glasses. The latter method allows more light to be transmitted, but is not so accurate as the former.

In the type of spectrophotometer which is especially adapted for the determination of concentrations, the light from a suitable source of illumination such as a frosted globe, glow-lamp, or an Auer burner, is divided into two beams and one of these passes through a layer of the solution to be investigated. The transmitted beam and the uninterrupted beam then traverse a prism system which causes each to be drawn out into a spectrum or a band of colors and thence they are transmitted through some sort of a photometric screen to the eye.

By means of a diaphragm a narrow region, only, of the spectrum is transmitted to the eye. Somewhere in the path of the two beams is inserted a device for bringing them to equal intensity and this device gives us a measure of the relative intensity of the two. The ratio of the intensity of the transmitted beam to the intensity of the uninterrupted beam gives us at once the extinction coefficient of the solution in question for the particular

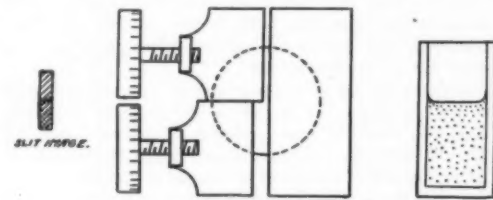


Fig. 3.—Double-slit apparatus.

color or wave-length of light employed. The commercial instruments accomplish these various ends in different ways, and we shall therefore consider some of the typical instruments in detail.

The factor A is, of course, different for each color, so that if it is determined for a particular color by means of a known extinction coefficient and a known concentration, in all subsequent work that particular color must be employed.

There is no mathematical relation between the extinction coefficient and the wave-length of light, but a relation may be determined experimentally by means of a spectrophotometer.

Let us consider a simple blue solution, for example, a salt of copper. The general character of the absorption curves for different concentrations is shown in Fig. 1.

The curves illustrated in the figure show the relation between the extinction coefficient and the color. The extinction coefficient is a measure of the absorption of the solution.

There are several facts to be observed about these curves which are of fundamental importance to *spectro-colorimetry*. Since the solution is blue the blue region of the spectrum is of course least absorbed, while the absorption in the red is the greatest.

A solution of zero concentration would transmit 100 per cent of the light incident upon it, neglecting the absorption of the solvent, and its extinction coefficient e would be $e = 2 - \log 100 = 0$. Its absorption curve would consequently be represented by the horizontal line A . A very dilute solution, say a concentration of 1 per cent, would transmit nearly 100 per cent in the blue but might transmit considerably less in the red, hence the shape of the 1 per cent curve.

Since e is directly proportional to c there is a constant difference between the successive concentration curves as shown in the figure. For instance, along the vertical line B , there is the same interval between curve 1 and 2 as between 2 and 3, etc. The same is true for the vertical line C or D , but the difference here in the red is

considerably greater than in the blue region, as might be expected.

It is therefore clearly seen that in working with weak blue solutions more accurate results could be obtained if the red part of the spectrum were utilized instead of the blue. With the ordinary colorimeter, what the eye sees is the resultant effect of all these colors, and since the blue predominates the solution appears blue.

The advantage of the spectro-colorimeter or the spectro photometer for accurate work is readily seen. The spectro photometer has this decided advantage over the spectro colorimeter, namely, that no standard solution is required. Moreover, only a small sample of the solution whose concentration is desired is necessary. The spectrophotometer may also be used for very dense and for very turbid solutions.

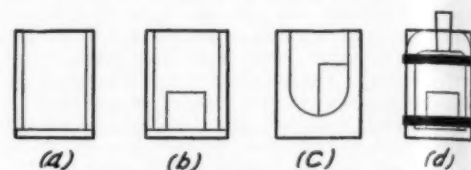


Fig. 2.—Different types of glass cells.

CELLS.

In making a photometric comparison of two light sources it is desirable that the two fields of view be uniform in intensity and that the boundary line between them be as small as possible. It is impossible to make an accurate setting when the two fields are separated by a line of any appreciable width.

Some instruments employ a simple rectangular glass cell; a , Fig. 2, and utilize the liquid surface of the solution to divide the incident beam. Due to the meniscus, however, the dividing line between the fields will not be narrow and this cell is therefore unfit for accurate work without some modification.

A glass cube, b , Fig. 2, with optically plane sides is sometimes employed, in which case the top surface of the cube forms the dividing line. This cell is often used where it is possible by special optical devices to separate the two beams a small amount before they reach the slit.

The third cell, c , has a curved bottom and the cube which is used with it also has a curved bottom so that when the latter is placed in the solution the sides of the cell and the sides of the cube will always be parallel.

The sides of these cells are either held together by cement or by means of clamps. The latter form of cell is more easily cleaned, and for some solvents this is an advantage.

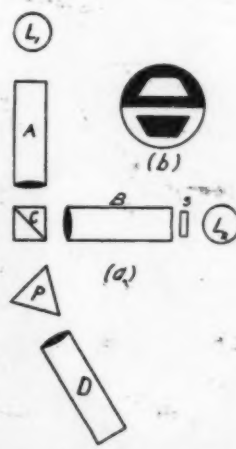


Fig. 5.—Lummer-Brodhun spectrophotometer.

In the case of volatile solutions it is well to use stoppered cells, d , Fig. 2.

THE KRÜSS UNIVERSAL SPECTRAL APPARATUS.

This instrument is similar to the ordinary prism spectrometer except that the collimator slit is double, and it is also provided with an ocular slit which excludes all of the spectrum except the desired color.

Each of the slits is actuated by means of a screw as shown in Fig. 3, and the screw heads are divided into 100 divisions. The cell is placed directly in front of and close to the slit face in such a manner that the level

of the liquid is in line with the dividing line between the two slits.

Upon looking through the eye-piece, with the ocular slit removed, one sees two spectra separated by an ill-defined line. If the cell with the cube is employed, this line may be made narrower and considerably sharper.

Now if the ocular slit is inserted and opened to a width of about 4 or 5 millimeters, two uniform folds of homogeneous light may be obtained. The ocular slit is, of course, magnified by the eye-piece, but in order to make a good setting it must not be too narrow. Moreover, homogeneous light is not obtained if the slit is open too wide. For example, if an observation were made upon a band narrower than the width of the slit, then it is readily seen that the field formed by the band would not be uniform, but would fall off in intensity to either side.

Care must also always be taken to avoid setting the ocular slit upon the edge of a band where the intensity changes rapidly. For instance, suppose that a particular blue solution (Fig. 1) were so concentrated that the red region of the absorption spectra could not be used. The yellow region would, of course, transmit more

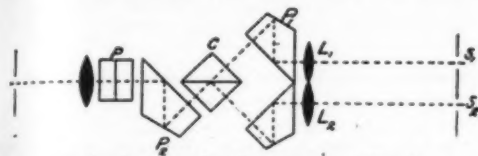


Fig. 6.—Lummer-Brodhun double collimator

light, and consequently make the photometric setting possible, but a slight change in the wave-length would introduce a considerable change in the intensity so that if the instrument were, for subsequent work, reset for the same color, this adjustment would have to be made with extreme care.

In the red or blue region, however, the curves are nearly horizontal, so that a considerable change in color is required to produce a significant error in the intensity.

With the type of slit shown in Fig. 3, a slight error will result if the difference in the widths of the upper and lower slit is too great, and it is consequently advisable to use a symmetrical slit, i. e., one in which both jaws of each slit open an equal amount, Fig. 4.

The scale which is attached to the telescope, or observing tube, of most of these instruments is either divided into circular degrees or arbitrary divisions so that the wave-length of light used cannot be read directly from the scale. This is not necessary, however, for it does not enter into any calculation and therefore an arbitrary scale is sufficient.

If, for example, the telescope reads 59.3 when the absorption ratio is determined for copper sulphate, then the telescope must always be set for 59.3 when this particular absorption ratio is used for the determination of the concentration of a copper sulphate solution.

Sometimes the principal solar absorption lines A, B, C, D, etc., are also engraved upon the scale, but they only serve as a rough universal scale. When one observer makes the statement that in a particular process the absorption ratio for a given substance should be determined in the region of the D line, then the process may be readily duplicated by the user of any type of instrument.

The method of making an observation with any double slit instrument is briefly as follows:

Both slits are opened to any convenient width, say to the 30 mark, and then the source of illumination is adjusted until the two spectra, as observed through the eye-piece, are equally bright. This adjustment must then be verified by resetting one of the slits, say the upper one, several times.

If the average of the readings thus obtained is 30 or very nearly 30, then the initial adjustment is sufficiently close. If, however, it deviates too much from 30, then

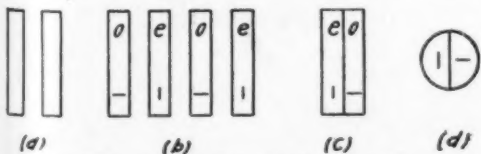


Fig. 8.—Spectra produced by the Koenig instrument.

the lamp must be shifted slightly and another series of readings obtained by operating the slit. This operation must be carried out until the upper slit reads the same as the lower one.

Both slits are then opened to the 100 mark and the cell containing the solution is placed in front of the slit face and adjusted until the level of the solution is in line with the dividing line between the upper and lower slit.

If the light is not too bright both slits may be opened to 100 instead of 30, and, moreover, if for subsequent

work, all the photometric balancing is to be done with the upper slit only, then it is, of course, not necessary that the lower one read 100 or any other particular number, so that when the lamp is roughly adjusted the upper slit may be set to 100 and the final adjustment may be carried out by means of the lower slit.

This method of making the initial balance is evidently much easier than adjusting the lamp. In making this initial balance the ocular slit may be set on any convenient color since both spectra are due to the same source and are therefore identical.

When the cell containing a colored solution is in position the lower spectrum will be weakened, and in order to bring both fields to the same intensity it will be necessary to narrow the upper slit.

Suppose an intensity balance is obtained when the upper slit is set at 30; that means that 30 per cent of the incident light is transmitted by the solution, and, therefore,

$$I'/I = 30/100.$$

whence from (2)

$$e = 2 - \log I' = 2 - \log 30 = 0.523.$$

If the concentration is 4 per cent, then the absorption ratio is

$$A = e/c = 4/0.523 = 7.65.$$

Now imagine that an unknown concentration of the same solute and solvent requires a reading of 24.0, on the screw-head of the upper slit for a balance, the extinction coefficient then becomes

$$e = 2 - \log 24.0 = 0.620.$$

and the unknown concentration is, therefore,

$$c = A/e = 7.65 \times 0.620 = 4.74.$$

This simple method admits of easy calculation, but for wide ranges of concentrations it is sometimes necessary to manipulate both slits. For extreme concentrations, the upper slit would have to be made so narrow that an accurate adjustment is impossible, since a very narrow slit means, of course, a considerable loss of light.

If we had a dense solution which would effect only a 3 per cent transmission instead of diminishing the upper slit to 3 we could set the lower slit to 300 and diminish the upper one to 9.

If several different widths of cells are used and if the absorption ratio is determined for each, then all the adjusting may be done with one slit. Since the concentration varies inversely as the length of the absorbing layer, if the absorption ratio is determined experimentally for one cell, it may be calculated for any other. For example, if the absorption ratio, A , is 8.24 for a 10 millimeter cell, then for a 20 millimeter cell it would be equal to 4.12.

Whenever the glass cube is used, the adjusting is, of course, always done with the lower slit.

When the two uninterrupted beams are first brought to equality, it is not necessary to have the empty cell in place while adjusting the lamp, since it causes the same absorption of each beam. However, if the glass cube is used, then its absorption will introduce a slight error which may be easily avoided by adjusting the intensity of the two spectra with the empty cell and cube in position. The error, however, is not worth considering when only approximate results are required since the transmission coefficient of 1 centimeter of glass is about 98 per cent.

Let us suppose that the instrument is first balanced without the cell in position and that the filled cell, with cube, requires for a balance a reading of 40 on the lower slit when the upper slit is set at 100. Neglecting the glass cube we obtain for the extinction coefficient

$$e = 2 - \log 40 = 0.398.$$

But since the cube transmits only 98 per cent of the light incident upon it and not 100 per cent, the true extinction coefficient is

$$e = \log 98 - \log 40 = 0.389.$$

In refined work the cell should always be filled with the solvent to be used and should be placed in position when the initial balance is made.

In order to eliminate the trouble of carefully adjusting the cell each time so that the top face of the cube is in line with the division line between the slits, a Schottlander double collimator or a Hufner reflecting prism is sometimes used in connection with the universal spectrometer, but as there are more precise instruments which do not require this delicate cell adjustment, these rather complicated appliances need not be considered.

LUMMER-BRODHUN SPECTROPHOTOMETER.

The usual form of the Lummer-Brodhun spectrophotometer is shown in *a*, Fig. 5.

A and *B* are two collimators, the slits of which are illuminated by two frosted globe incandescent lamps (16 candle-power, 110 volts). The telescope *D* is provided with a slit instead of an eye-piece, so that on placing the eye close to this slit one sees the face of the Lummer-Brodhun cube, *C*, which has the appearance shown in *b*, Fig. 5.

The dispersive prism, *P*, spreads the light into a spectrum so that there is a succession of colored images of the cube in the plane of the ocular slit. Since, however, the slit transmits only a narrow region of the

spectrum, the eye sees the cube illuminated in only one color.

The cell *S* may be placed before either slit and since the two slits are independent of each other the illumination may be controlled by moving either lamp to or from the slit it illuminates. Thus with the cell filled with the solvent, in front of one of the slits both may be set to the 100 mark and the initial balance made by adjusting the lamps or by simply manipulating the slit which receives the absorbed light from the cell. The other slit must, of course, be kept at the 100 mark.

The disadvantage of this type of photometer over that in which both slits are illuminated by the same source is that the two lamps must be kept constant,

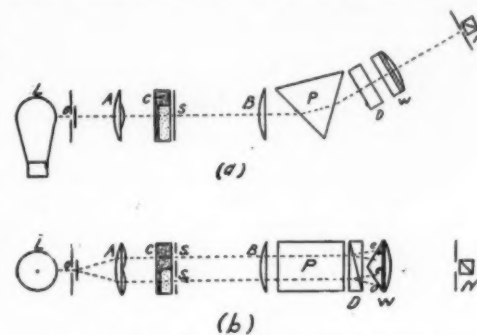


Fig. 7.—Koenig-Martens spectrophotometer.

but in the latest form of this instrument the lamps are rigidly clamped to the frame of the instrument so that the only change in intensity that may occur is that caused by fluctuations of the voltage. Although both lamps are on the same circuit and subjected to the same change in voltage, it does not follow, of course, that the corresponding change in intensity is the same in each lamp. This would be the case if both lamps were practically similar, and it is not difficult to select two lamps which will fulfil all industrial requirements.

If the lamps appear equally bright to the unaided eye and if they balance for all parts of the spectrum, there will be no appreciable difference in their intensity due to an increase or decrease of the voltage. The initial balancing of the two fields will then hold good for a number of hours of constant use.

With this type of Lummer-Brodhun spectro photometer it is only necessary to have the solution cover one of the slits and the time saved in adjusting the cell more than compensates for the time required to re-balance the two fields in order to make sure that a change of voltage has not disturbed the original balance.

In order to make a photometric balance with the type of Lummer-Brodhun cube shown in *b*, Fig. 5, the light from one source is varied by adjusting one slit until the semi-circular portions have the same brightness, and when this condition obtains the two quadrangles will be equally bright, but there is always a slight difference in their brightness and the brightness of the semi-circular backgrounds. Such an arrangement is known as a *contrast photometer*, and it is much more sensitive than the ordinary type.

The observing tube is provided with a scale which is

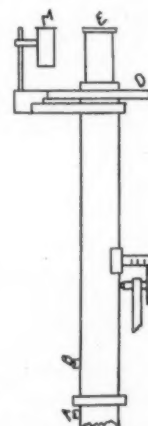


Fig. 9.—Observing tube of the Koenig-Martens instrument.

read by means of a small telescope and miniature 6-volt glow-lamp. The lamp is usually run on three storage-battery cells, and as the scale cannot be seen without the aid of this lamp the arrangement is not practical, since all commercial laboratories are not provided with storage batteries. The screws actuating the slits are not within easy reach when the eye is at the observing tube, and, moreover, the divisions on the screw heads cannot be read from the position occupied by the observer when looking through the observing tube.

These disadvantages are overcome in some other instruments which lack the accuracy of the Lummer-Brodhun. To be sure, these points have nothing to do with the working principle of the instrument; however, they are very essential to the operator whose time is valuable, and the failure to appreciate their importance has in many instances retarded the progress of such methods in industrial laboratories.

For industrial purposes it is far better to employ an instrument by means of which one may obtain quickly a large number of fairly accurate observations than to employ a very sensitive instrument which requires more time to make a very few extremely accurate observations. In using any instrument which requires the eye to match colors or balance intensities the best method of making certain that your results are correct is to repeat the observations.

By means of a double collimator and reflecting prisms, the Lummer-Brodhun cube may be adapted to the double slit photometer. The optical system of the Lummer-Brodhun double-slit instrument is shown in Fig. 6.

Light from a suitable source of illumination passes through the double slit S_1 and S_2 , is rendered parallel by means of the two lenses L_1 and L_2 , and thence passes to the Lummer-Brodhun cube, C , by means of the reflecting prism P_1 . By means of a second reflecting prism P_2 the light is transmitted through the dispersive prism P , which draws out the image of the Lummer-Brodhun cube into a spectrum.

If the lamp is fastened rigidly to the frame of the instrument then a change in its intensity, due to a change in voltage, will not cause any error in the determination of e , since the light through both slits is changed in the same ratio.

KÖNIG-MARTENS POLARIZATION SPECTROPHOTOMETER.

The optical system of this instrument is shown in Fig. 7; a is a horizontal section through the instrument, and b a vertical section.

Light from a suitable lamp L passes through a small aperture, O , which is covered with ground glass. By means of a double lens, A , two parallel beams are produced which illuminate the two slits, S_1 and S_2 . A cell of the type shown in c , Fig. 2, is placed in front of the two slits.

The slits are thus always equally illuminated regardless of the position of the lamp, since the two beams originate from the same source of light. If the lamp were moved slightly to one side, the ground glass would still be uniformly illuminated. In reality, the two slits are one, which is divided by means of a tongue, hence they are always open the same amount.

From the slits the light is again rendered parallel by a lens, B , and by means of a dispersive prism, P , the slit images are spread out into two spectra, a , Fig. 8, which are separated several millimeters.

These two spectra are next divided into four, b , Fig. 8, by means of a double-image prism, D . The ordinary and extraordinary images thus produced are plane polarized with their vibrating planes mutually perpendicular. The short horizontal and vertical lines in b , c and d indicate the direction of vibration.

By means of a wide angle wedge, W , which is part of the telescope objective, the two inner images are thrown together, c , Fig. 8, while the outer images are excluded from the telescope.

When the eye is placed at the ocular slit, which is in the focal plane of the telescope objective, it sees the wide angle wedge, W , illuminated by light of one color. As the telescope or observing tube is rotated about an axis through the prism, P , thus causing the ocular slit to pass from one end of the spectra to the other, the field is alternately illuminated by the prismatic colors, red, yellow, green, etc. The field of view has the appearance shown in d , Fig. 8.

If a Nicol prism, N , Fig. 7 (i. e., a prism which transmits only plane polarized light), is placed between the eye and the ocular slit with its transmission plane vertical, the left field will appear bright, but the right one dark, since it is illuminated by light whose vibrations are perpendicular to the transmission plane of the Nicol.

When the Nicol is placed with its transmission plane horizontal, it will transmit light from the right field but exclude all light from the left one so that the left field appears dark.

Now, if the Nicol is turned 45 degrees both fields will appear equally bright, and for any other position of the Nicol the ratio of the intensity of the light from S_1 to the intensity of the light from S_2 is expressed by the simple relation

$$I_1/I_2 = \tan^2 \phi$$

where ϕ is the angle through which the Nicol must be turned to produce a photometric balance.

If the cube covers slit S_1 , then the cotangent is used instead of the tangent.

From the theory of extinction coefficients

$$e = -\log (I/I_0)$$

But I_1/I_2 is the ratio of the transmitted light to the incident light if the instrument is balanced when the

Nicol scale reads 45 degrees and the empty cell is in the position indicated, hence the extinction coefficient is

$$-\log (I_1/I_2) = -\log \tan^2 \phi = 2 \log \cot \phi.$$

The absorption ratio, A , is a constant, so that the factor 2 may be dropped. For this particular instrument we may define the extinction coefficient by the equation

$$e = \log \cot \phi.$$

The concentration then becomes

$$c = A e = A \log \cot \phi.$$

The log cotangent of the angle through which the Nicol must be turned in order to produce a photometric balance, may be obtained directly from a logarithmic table, so that when the reading of the Nicol scale is obtained, the extinction coefficient is readily determined.

The method of determining the concentration of a particular solution by means of observed data may be made clear by a simple calculation. Suppose a 10 per cent solution gives a reading of 26.4 (i. e., 26 degrees 24 minutes) on the Nicol scale. The extinction coefficient is from the above equation

$$e = \log \cot \phi = \log \cot 26.4 = 0.304$$

and the absorption ratio is therefore

$$A = e/c = 10/0.304 = 32.9.$$

If an unknown solution gives a reading of 18.6 degrees its concentration is found to be

$$c = A e = 32.9 \log \cot 18.6 = 15.5 \text{ per cent.}$$

The Nicol prism is attached to a circular disk, D , Fig. 9, which is divided into angular degrees, and this scale is observed by means of a small magnifier, M , which is close to the eye-piece, E .

The telescope, or observing tube, is rotated by means of a screw, S , the head of which moves over a scale divided into arbitrary divisions. This scale is used for indicating a particular position in the spectrum.

This instrument has several distinct advantages over others described. The two slits have always the same width, and this prevents any asymmetry of spectra. The device for varying the intensity is within easy reach and the attached scale may be quickly and accurately read by moving the eye a short distance. The screw that rotates the observing tube is also within easy reach and the observing tube scale may be easily read from the position occupied by the observer when making a photometric balance. All of the optical parts are completely enclosed, and this makes the instrument more robust. Moreover, all extraneous light is excluded.

Owing to the rather complicated optical system, however, this instrument only transmits about one third as much light as the double-slit spectro photometer, and this fact renders it unsuitable for very concentrated solutions. This difficulty may be overcome to some extent by using cells of short length. In the most improved form of this spectrophotometer, rather long cells may be used so that observations may be made on very dilute solutions. It is thus seen that the instrument has considerable range.

Both the double-image prism and the wide-angle wedge may be rotated slightly by means of set-screws, A and B , Fig. 9, so that when the Nicol is set at 45 degrees the two fields may be brought to equality. It is never necessary to repeat this adjustment after the instrument is once set up, unless it receives some rough handling which might disturb the optical system.

The method of completely calibrating a spectrophotometer and some industrial applications of the spectrophotometer will be fully considered in a concluding article.

(To be concluded in issue of April 11th).

Intensity of Hertzian Waves Varies According to the Weather

THE intensity of the signals emitted by the posts of wireless telegraphy varies not only at different hours of the day, but also at different periods of the year. Extremely interesting researches on the variation of the intensity of radiotelegraphic signals have just been made by Prof. E. W. Marchand between Liverpool and Paris, and by Prof. Mossler in Germany. During a year, Prof. Mossler had measured both by day and night, by means of a detector and a galvanometer, the intensity of a current of reception in a station of wireless telegraphy situated at a distance of 425 kilometers toward the coast. He has remarked that during the day the intensity is not influenced by the height of the sun, and that this intensity remains constant for all the year, but that the characteristic maxima values are manifested during the night in autumn and in spring. In general Prof. Mossler observes that in summer one cannot reckon on a night reach of intensity much greater than of the day during the colder season. During the night very strong increases of intensity are remarked, which disappear rapidly. It would seem that they are to be attributed to the changes of ionization of the higher atmosphere. In spite of very minute measurements no influence exercised by the brilliancy of the moon on the intensity of the signals has been observed. The observations of M. Marchand are not less curious. It is signals sent off by the Eiffel Tower

at 10:45 o'clock in the morning and at 11:45 in the evening which have served him as a point of comparison. The result of these experiments shows that the maximum of variation of diurnal intensity of the signals during the same month is from 0.6 to 1.3, the average intensity being 1.1. On a fine clear night the signal has an intensity equal to 1.7 times that of the day signals. The meteorological state affects the intensity of the signals emitted and received. In Paris the rain always decreases the intensity of the reception. A wind blowing from the northwest at a speed of 6 meters per second has once lowered by one half the normal intensity of reception. Cloudy weather is the most favorable for the transmission and reception of wireless telegraphy signals. If the sky is clear, or if there are only light clouds, the signals are weaker. The rain at the receiving station does not appear to have any great influence on the intensity of the Hertzian waves. A curious fact observed by M. Marchand and by the officers of the military wireless telegraphy is the strengthening of the intensity of the signals immediately after sunset, which increase has sometimes amounted to 70 per cent. The intensity of the signals remained constant after the sudden strengthening. The explanation of these diverse phenomena still remains mysterious.—*Chemical News*.

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